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VOLUME 24 JANUARY, 1950 NUMBER 1

TERTIARY NAUTILOIDS OF THE AMERICAS: SUPPLEMENT

A. K. MILLER AND H. R. DOWNS
State University of Iowa, Iowa City, Iowa

ABSTRACT—Representatives of *Eutrephoceras* are described from the Paleocene and the Eocene of California; *Cimomia* from the Paleocene of Colombia and Trinidad and the Eocene of Washington; *Hercoglossa* from the Paleocene of Baja California and the Eocene of Peru; *Deltoidonautilus* from the Eocene of Peru; and *Aturia* from the Eocene of Texas, California, Washington, and Peru, and Oligocene of Oregon and Washington, and the Miocene of California, Florida, and Cuba. All of these specimens that merit illustration are figured. A representative of *Aturia* from the Miocene of Sinai is discussed in an appendix, and illustrations of it are included.

LATE in 1947 The Geological Society of America published a monograph of the "Tertiary nautiloids of the Americas" by the senior author of the present report. Since that time, various paleontologists have sent in additional specimens from widely separated localities. We propose to treat all of this material in a single publication, which can therefore be regarded as a supplement to the recently published monograph.

The specimens on which this report is based became available to us through the courtesy of the following persons: Dr. P. J. Bermúdez of the Creole Petroleum Corporation (Caracas); Professor Bernardo Boit of the Universidad de San Marcos; Professor J. Wyatt Durham of the University of California (Berkeley); Dr. Julia Gardner of the United States Geological Survey; Dr. A. Myra Keen of Stanford University; Dr. H. G. Kugler of the North Venezuelan Petroleum Company, Limited (Caracas); Mr. Chas. R. Locklin of Union Lake (near Pontiac), Michigan; Professor Norman D. Newell of The American Museum of Natural History and Columbia University; Professor W. P. Popenoe of the University of California (Los Angeles); Dr. H. H. Renz of the Mene Grande (Gulf) Oil Company (Caracas), and Sr. Pedro Verástegui M. of Stanford University. Special acknowledgment is also due to Professor Don L. Frizzell of the Missouri School of Mines and Metallurgy for advice in regard to certain Peruvian strata, and especially to Mr. Howard Webster of Iowa City who retouched the photographs and made the drawings which accompany this study. The completion of the report was made financially possible by the Graduate College of the State University of Iowa.

Much of the material discussed in this supplement is from the collections of the University of California at Berkeley, and it came from various horizons and localities in our Pacific coast Tertiary. It should perhaps be mentioned in this connection that Professor J. Wyatt Durham has informed us that it is now generally believed that all of the Paleocene Martinez formation of California is as old as the Midway group

of the Gulf Coastal Plain, and that some of it may be older. If this belief is correct *Aturia*, and possibly also *Aturoidea*, were almost certainly represented on our west coast long before they appeared on our Atlantic-Gulf coast. Professor Ewart M. Baldwin of the University of Oregon has written us that the formation at Dallas, Oregon, which yielded the holotype of *Eutrephoceras oregonense* Miller, is not Oligocene in age (as stated in the original description of the species) but is Eocene, "probably equivalent to the Domengine stage of California. Similar limy beds nearby, which also contain what I [Baldwin] believe to be these same nautiloids, contain large Foraminifera assigned to *Pseudophragmina psila* (Woodring), which tends to support the older Eocene age." Both Professors Durham and Baldwin have assured us that no Pliocene strata are known in the coastal area west of Eugene from which Dall (1909, p. 21) stated that Thomas Condon had collected a "fine" nautiloid. Professor Baldwin adds that the "rock that would come the closest to being called Pliocene is that at Newport, where Dr. Condon spent many of his vacations. This is now considered to be a part of the Astoria formation of approximately middle Miocene age. The only marine Pliocene that we know of in Oregon is the Empire formation at Coos Bay and the Empire and Port Orford formations at Cape Blanco."

A discussion of a few sporadic specimens is also included in this report. One of these, which represents a new species of *Hercoglossa*, is the first Tertiary nautiloid to be recorded from the Pacific coast region of Mexico—it came from the Paleocene of Baja California. Another is an exceptionally well preserved internal mold of *Aturia brazoensis* Stenzel from the lower part of the Eocene Claiborne group of east Texas. Two others are delicate testiferous representatives of *Aturia curvilineata* Miller and Thompson from the Miocene Chipola formation of the Florida panhandle. A fifth is a representative of the rare species *Aturia cubanensis* (Lea) of the Miocene of Cuba; and along with the discussion of it is included some data on the occurrence in Cuba of other congeneric forms. A sixth is a small fragment of a conch from the Paleocene at a locality in northern Colombia from which no nautiloids had previously been recorded in the literature. A seventh is an essentially complete internal mold from the Paleocene in the Marac quarry of Trinidad, and it is probably referable to *Cimomia subrecta* Miller and Thompson, which was originally described from the Midway group of our Gulf Coastal Plain. An eighth is an exceptionally fine large internal mold of *Hercoglossa peruviana* Berry from the Eocene of Peru. A ninth is a small representative of the genus *Aturia* from the Miocene of Sinai.

The other material described in this report is a collection made by Sr. Pedro Verástegui M. from the Salina formation and the Lomitos sandstone (which was formerly regarded as a member of the lower Talara shale) in northwestern Peru. It consists of an immature representative of *Deltoidonautilus* from the Salina, and *D. haughti* (Olsson) and *Aturia peruviana* Olsson from the Lomitos. The occurrence of the genus *Deltoidonautilus* in South America is being recognized for the first time.

Altogether, we are describing (and in most cases illustrating) representatives of the following genera: *Eutrephoceras* from the Paleocene (Martinez) and the Eocene (Capay) of California; *Cimomia* from the Paleocene of Colombia and Trinidad (Sol-

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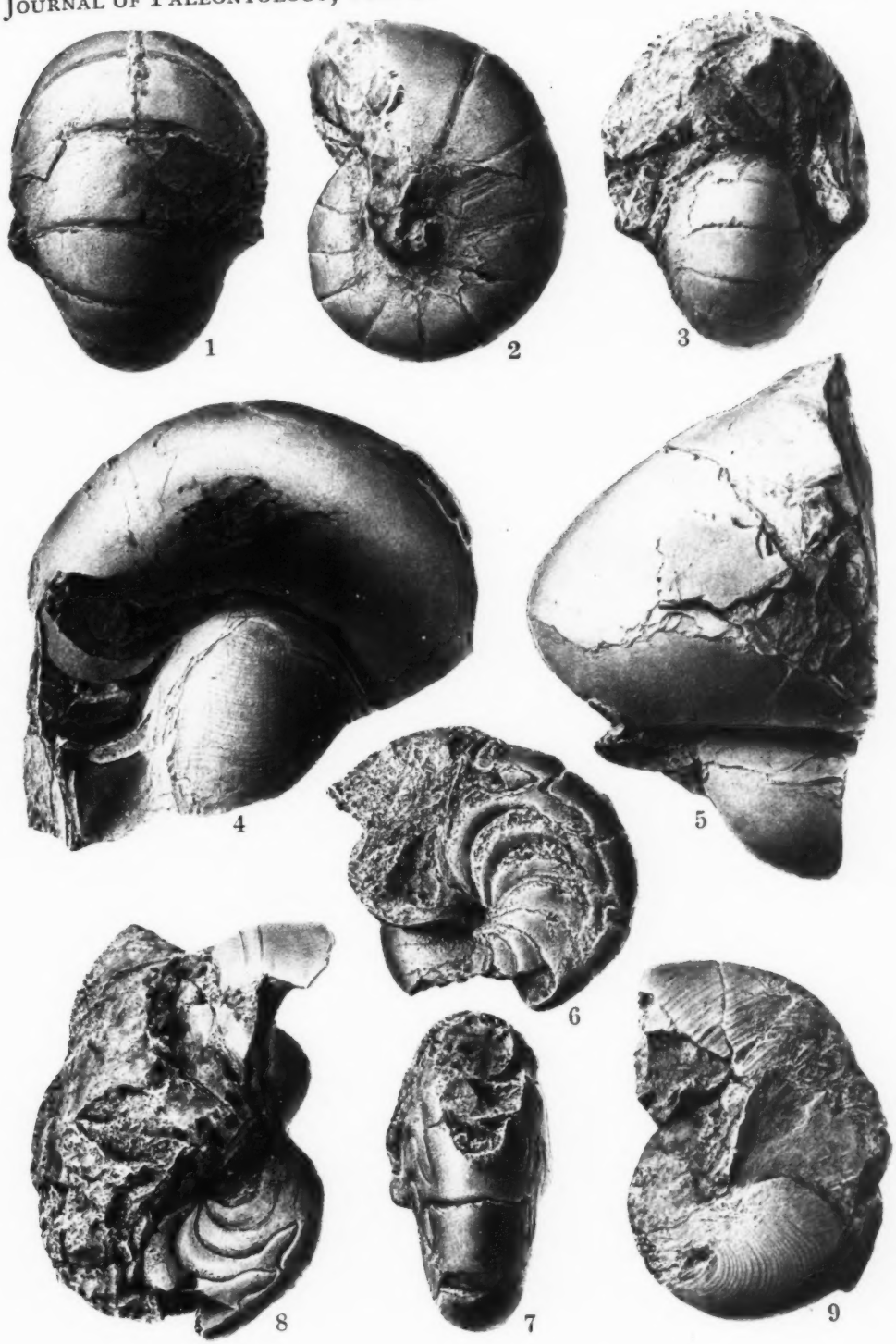
EXPLANATION OF PLATE 1

FIGS. *1–3*—*Eutrephoceras* sp. Three views of a small specimen from the Eocene Capay shale about 4 miles west of Winters, California, ×2. (p. 3)

4, 5—*Eutrephoceras* aff. *E. stephensoni* (Dickerson). Two views of a portion of a phragmacone from the Paleocene Martinez formation near Selby station, California, ×1. (p. 3)

6–8—*Aturia angustata* (Conrad)? Two moderately small specimens from the Oligocene Twin Rivers formation an eighth of a mile east of the city of Twin Rivers (figs. *6*, *7*), and in a sea cliff east of the mouth of East Twin River (fig. *8*), Washington, ×2 and ×1, respectively. (p. 9)

9—*Aturia* sp. Lateral view of a rather poorly preserved testiferous specimen from the Eocene Crescent formation in a sea cliff near Port Crescent, Washington, ×1. (p. 15)



Miller and Downs, Tertiary nautiloids

2

1

Miller and Downs, Tertiary nautiloids

dado) and the Eocene (Cowlitz) of Washington; *Hercoglossa* from the Paleocene of Baja California and the Eocene of Peru; *Deltoidonautilus* from the Eocene of Peru; and *Aturia* from the Eocene of Texas, California, Washington, and Peru, the Oligocene of Washington and Oregon, and the Miocene of California, Florida, Cuba, and Sinai.

SYSTEMATIC PALEONTOLOGY

EUTREPHOCERAS aff. E. STEPHENSONI (Dickerson)

Plate 1, figures 4, 5

Eutrephoceras stephensoni? VOKES, 1937, Jour. Paleontology, vol. 11, p. 5; MILLER, 1947, Geol. Soc. America, Mem. 23, p. 37.

When Vokes discussed *Eutrephoceras stephensoni* in 1937, he stated: "There is in the collections at the University of California a fragment of a very large specimen from the Martinez formation near Selby Station, California, which may represent this species. The greatest width of the conch was 85 mm., and the distance from the venter to the base of the impressed area over 30 mm. It is too globose to be referable to *E. hallidayi*, but is too imperfect to permit definite specific determination."

This specimen represents parts of two (or more) volutions of a phragmacone, the preserved portion of which is estimated to have been a little less than 100 mm. in diameter. The shape of the cross section of the conch is elucidated by figure 4 on plate 1. The surface of the test of at least the penultimate of the volutions represented is reticulate as it is marked by moderately coarse longitudinal and transverse lines, which are of about equal size and prominence. The transverse ones, growth lines, indicate that the conch bore a broad rounded hyponomic sinus. The siphuncle is small and is located moderately close to the dorsal wall of the conch. Where the distance between the dorsum and the venter measures about 20 mm., the siphuncle is about 2 mm. in diameter, and its center is about 6 mm. from the dorsum and 14 mm. from the venter.

Remarks.—The large size and particularly the reticulate surface ornamentation of the test of this specimen indicate that it is almost certainly not referable to *E. stephensoni;* and as Vokes stated, its conch is relatively wider than that of *E. hallidayi* (Waring), the only other congeneric form known from the Martinez formation. It probably represents an unnamed species, but it would not make a satisfactory holotype.

Occurrence.—Martinez formation about 200 ft. northwest of the south portal of the Southern Pacific railroad tunnel near the smelter at Selby station, Contra Costa County, California.

Repository.—University of California, Berkeley.

EUTREPHOCERAS sp.

Plate 1, figures 1–3

In June of 1938 Miss Herdis Bentson found the only nautiloid known from the Eocene Capay shale of California. It is an internal mold that is septate throughout and is about 26 mm. in diameter—its maximum width of conch measures about 19 mm. The umbilicus is small and inconspicuous, and in one of the umbilical depressions (pl. 1, fig. 2) there is a "plug" of shell material which indicates that the conch, when complete, consisted of at least one more full volution. The external sutures are essentially straight and directly transverse, and the camerae are of about average length. A structure that appears to represent the siphuncle is small and is subcentral in position.

Remarks.—Clearly this specimen belongs in the genus *Eutrephoceras.* However, its preservation leaves much to be desired, and its small size and general physiognomy indicate that it probably represents only the immature portion of the conch. Therefore, we are reluctant to express an opinion in

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EXPLANATION OF PLATE 2

FIGS. *1, 2*—*Cimomia subrecta* Miller and Thompson. Lateral and apertural views of a specimen, from the Paleocene Soldado formation in Marac quarry, southern Trinidad, British West Indies, very slightly less than ×1. (p. 4)

regard to its specific affinities, but it may well be referable to *E. hannai* Vokes.

Occurrence.—Capay shale (65–90 feet stratigraphically below the Pliocene conglomerate contact) at the Fenn Ranch locality, just above the stream bottom, about 4 miles west of Winters, Yolo County, California—it was found in association with brachiopods and *Venericardia*—[loc. A3073].

Repository.—University of California, Berkeley.

CIMOMIA HESPERIA M. & D., n. sp.
Plate 3, figures 3, 4

The holotype of this species is an internal mold which represents much of four camerae of a phragmacone. Its whorls are helmet-shaped in cross section as they are broadly rounded ventrally, flattened laterally, and impressed dorsally. Clearly, the conch, when complete, was subglobular, The over-all length of the holotype measures about 66½ mm.; and at the uncrushed septum which forms its adapical end its height and width of conch measure approximately 38 mm. and 45 mm., respectively, and the depth of the impressed zone is about 12½ mm. The umbilical shoulders are rounded, and apparently the umbilicus is small.

Fragments of the test which adhere to this specimen are thin. Traces of the growth lines that are preserved on them show that there was a broad shallow rounded hyponomic sinus.

The camerae are moderately long. Each suture forms a low broad rounded ventral saddle and on either side of it a similar but smaller lateral lobe, a small but rather prominent saddle on the umbilical shoulder, a slight lobe on the umbilical wall, and a low broadly rounded internal lateral saddle which extends to the similar but medianly flattened dorsal lobe.

The siphuncle is small, and is subcentral in position, but is located considerably closer to the dorsum than the venter. At the adapical end of the holotype, the siphuncle is about 2 mm. in diameter and its center is about 10½ mm. from the dorsum and 15 mm. from the venter. It appears to be composed of cylindrical segments and presumably is orthochoanitic in structure as in other congeneric species.

Remarks.—This form is the first representative of the genus *Cimomia* to be recorded from the Pacific coast region of North America. Its most distinctive characters seem to be the shape of its cross section and its sutures. It is not particularly close to any of the congeneric species that have been described from our Atlantic-Gulf Coastal Plain or from South America, probably because most of them are from older (that is, Paleocene) strata.

The collections of the University of California at Berkeley contain a very fragmentary specimen which is probably conspecific with the holotype just described. It came from the same general horizon and locality as the holotype, and it seems to represent an individual of about the same size. However, it is so distorted and incomplete that its affinities will always be open to question. Both of these specimens were collected by Professor J. Wyatt Durham.

Occurrence.—Type section of the upper Eocene Cowlitz formation at the big bend in the Cowlitz River (a well-known locality), Lewis County, Washington.

Holotype.—University of California, Berkeley.

CIMOMIA SUBRECTA Miller and Thompson
Plate 2, figures 1, 2

Cimomia subrecta MILLER and THOMPSON, 1933, Jour. Paleontology, vol. 7, pp. 308–311, pl. 35, figs. 1, 2; STENZEL, 1942, [Illustrated card catalogue of North American early Tertiary fossils of Atlantic-Gulf Coastal Plain], Cephalopoda, cards 9a, 9b; SHIMER and SHROCK, 1944, Index fossils of North America, p. 550, pl. 225, fig. 6; MILLER, 1947, Geol. Soc. America, Mem. 23, pp. 4, 6, 42, 46–47, 48, 49, pl. 31, figs. 1, 2.

Dr. H. G. Kugler recently sent us for study a rather large specimen from the Paleocene of Trinidad that should probably be referred to Miller and Thompson's species. However, as explained below, it may well be specifically distinct.

This specimen is an essentially complete internal mold which is only slightly distorted. Its maximum diameter is about 140 mm., and near its adoral end the maximum height and width of its conch measure about 83 mm. and 88 mm., respectively. The umbilicus, though deep, is small and inconspicuous, and the umbilical shoulders are rounded and indefinite. No trace of the surface markings of the test is preserved. The nature of

the sutures and the general physiognomy of the specimen are elucidated by the accompanying illustrations.

Remarks.—It is clear from a direct comparison of this specimen with the holotype of *C. subrecta* that the saddles on the umbilical shoulders are much less prominent on the Trinidad individual. However, in the extreme adoral portion of the phragmacone of the holotype, those saddles become relatively low. In both specimens the adoral camera is considerably shorter than the preceding one, indicating that we are dealing with fully mature individuals in each case; but the Trinidad specimen is about 20 per cent larger than the holotype. Nevertheless, most of the other characters of the two do not seem to differ materially, and therefore we are tentatively regarding them as conspecific.

Occurrence.—Soldado formation (Paleocene) in the Marac quarry in the south-central part of Trinidad, British West Indies. All of the specimens that have previously been referred to this species came from the Clayton formation (the basal part of the Paleocene Midway group) of Mississippi.

Repository.—Museum of Natural History at Basel, Switzerland.

CIMOMIA? sp.
Plate 3, figure 7

Professor J. Wyatt Durham loaned us a fragment of a nautiloid which he secured from the Paleocene of northern Colombia at a locality where no representatives of this order had been found previously. Most of the beds exposed there are essentially non-fossiliferous; but one of them contains an abundance of small gastropods, pelecypods, and other fossils, and the nautiloid was found in it.

This specimen consists of umbilical and adjacent portions of a moderately small individual—its maximum over-all measurement is only about 30 mm. The umbilicus is small and closed, and the umbilical shoulders are rounded and indefinite. The surface of the preserved portion of the test is marked by fine transverse lines (presumably growth lines) that are slightly sinuous.

The general physiognomy of this specimen seems to us to be reminiscent of *Cimomia*, and none of its characters that we are able to ascertain militates against this generic reference. However, it may well belong in such genera as *Eutrephoceras*, *Hercoglossa*, or *Deltoidonautilus;* and with no knowledge as to the shape of its sutures we can, of course, not determine its generic affinities.

Occurrence.—A buff-colored limestone bed in a Paleocene brown shale which outcrops "in a small quebrada about 450 meters west of the village of Manantial, along the Hato Nuevo-Manantial trail, about 12 kilometers northeast of Hato Nuevo, Departamento de Magdalena, Rancheria Valley, Colombia."

Repository.—University of California, Berkeley.

HERCOGLOSSA PERUVIANA Berry
Plate 6, figures 1, 2; Plate 7, figure 2

An exceptionally fine large representative of this species was sent to us for study through the courtesy of Professor Norman D. Newell, who borrowed it from the Engineering School in Lima, Peru. This specimen is an internal mold to which a considerable portion of the test (or a replacement of it) adheres. It is preserved in mottled light brown limestone and is only slightly distorted. Inasmuch as it is septate throughout, it represents only phragmacone. When complete, the conch was at least another half-volution in extent.

The maximum diameter of this individual, measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen, is about 225 mm. The maximum height and width of the preserved part of the conch measure about 140 mm. and 150 mm., respectively; and near the adoral end of the specimen the impressed zone is almost 50 mm. deep. The diameter of the complete shell is estimated to have been more than 400 mm.

The test of the adapical portion of the outer volution is about 1 mm. thick. On the surface of the test there are numerous fine growth lines. Each of these forms a deep rather narrowly rounded ventral or hyponomic sinus and on either side of it a broad rounded asymmetrical lateral salient that extends clear to the umbilicus. No trace of the growth lines is discernible on the internal

mold, but along its venter there is a rather prominent raised line.

There are some 20 camerae in the outer volution of this specimen. The sutures and the siphuncle appear to be typical of the species. At its passage through the adoral septum, the siphuncle is about 8 mm. in diameter.

Remarks.—Recently, Miller (1947, pp. 58–59, pl. 23, fig. 2; pl. 24, figs. 1, 2; pl. 25, figs. 1, 2; pl. 89, figs. 1, 2; pl. 90, fig. 4) described this species in detail, listed its complete synonymy, and indicated how it can be distinguished from the very similar form, *H. ulrichi* (White). There is of course no need to duplicate that work here.

Occurrence.—Near Lobitos, Peru presumably from the Talara formation. Olsson (1928, p. 96) has stated that this species is "strictly limited" to one "horizon" and is "quite common" in it; and Frizzell has recently written us that it occurs "in the lower part of the Talara formation in beds that . . . [are] near the top of the middle Eocene." Furthermore the lithology and preservation of the specimen, which are very distinctive, are precisely like those of conspecific individuals near Lobitos.

Repository.—School of Engineering, Lima, Peru.

HERCOGLOSSA POPENOEI M. & D., n. sp.
Plate 5, figures 1, 2

On February 14, 1948, Professor W. P. Popenoe (and party) found a large well preserved representative of *Hercoglossa* in the northern half of Baja California and kindly loaned it to us for study. This form is not referable to any described species, and we propose to name it in honor of its discoverer.

The holotype of the new species appears to be fairly complete, and it attains a maximum diameter of about 270 mm. Its adoral half-volution is non-septate and presumably therefore represents living chamber. Near the junction of the phragmacone and the living chamber, the conch is essentially free from distortion and it is about 108 mm. wide and 100 mm. high. The whorls are rather narrowly rounded ventrally, strongly flattened (but very broadly rounded) laterally, and deeply impressed dorsally. The lateral zones converge ventrally, and therefore the maximum width of conch is attained at the umbilical shoulders. These shoulders are rounded, and the umbilicus is small, closed, and inconspicuous.

The test is fairly thick, and at the junction of the phragmacone and the living chamber its thickness along the ventrolateral zone measures almost 3 mm. For the most part, only the inner layers of the test are retained on the holotype. However, from preserved portions of the outer layer, it can be ascertained that the surface bears small low inconspicuous ribs and fine growth lines which are parallel to them. Each of these forms a broad deep rather narrowly rounded ventral sinus and on either side of it a low broad rounded lateral salient which extends to the umbilicus.

The length of the adoral camerae of the holotype, measured along the venter, varies from about 19 to 23 mm. The adoral camera of this specimen is distinctly longer than the preceding one. As shown by text figure 1, each external suture forms a broad high rounded ventral saddle, and on either side of it a deep rather narrowly rounded lateral lobe and a high rounded lateral saddle which extends to the umbilical shoulder.

EXPLANATION OF PLATE 3

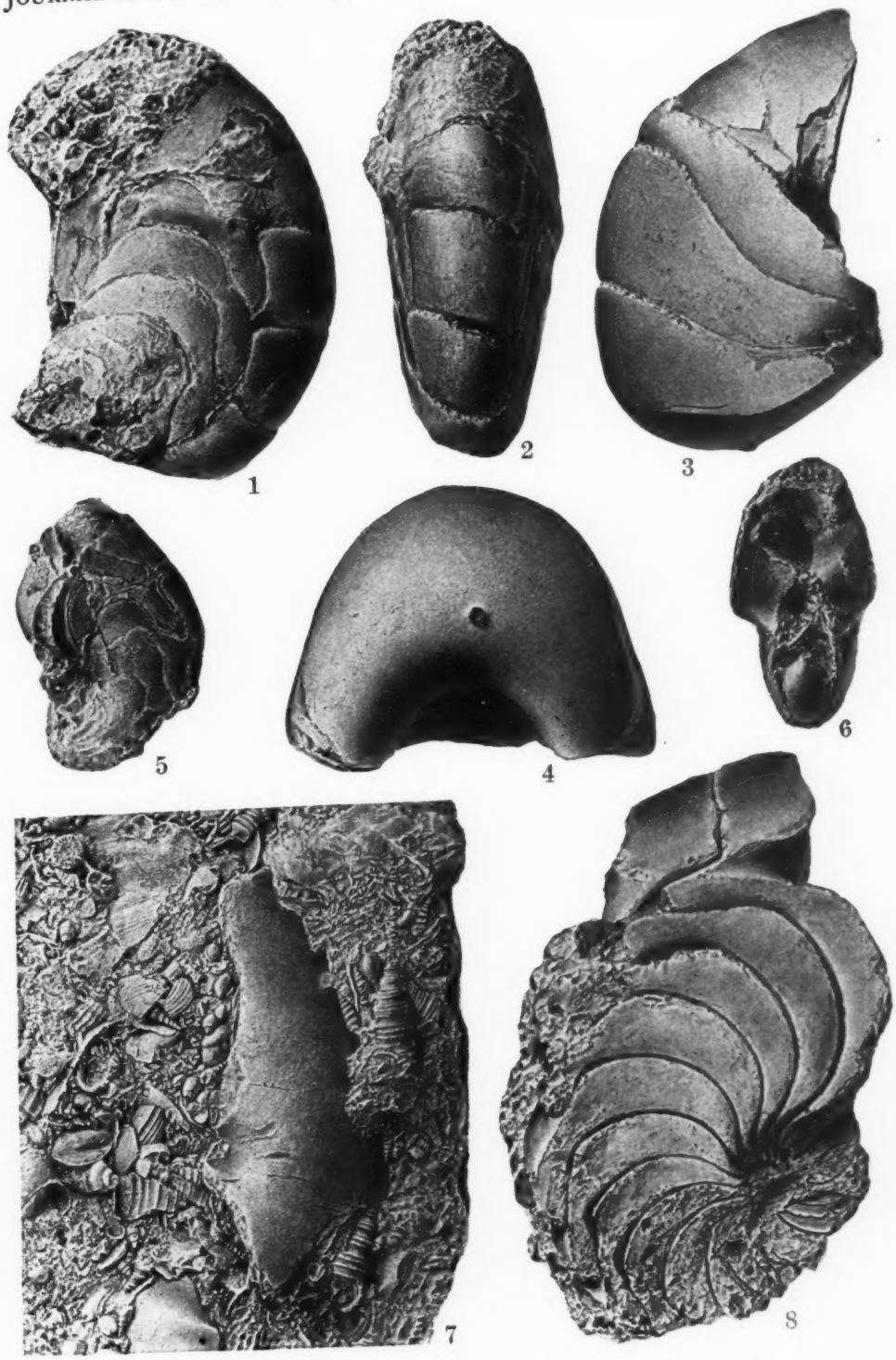
FIGS. *1, 2*—*Aturia* sp. Two views of an internal mold, from the Vacaville shale member of the Eocene Capay formation about half a mile north of "Black Rocks" in Putah Creek, Yolo County California, ×1. (p. 15)

3, 4—*Cimomia hesperia* M. & D., n. sp. Lateral and apical views of the holotype, from the Eocene Cowlitz formation at the big bend in the Cowlitz River, Lewis County, Washington, ×1. (p. 4)

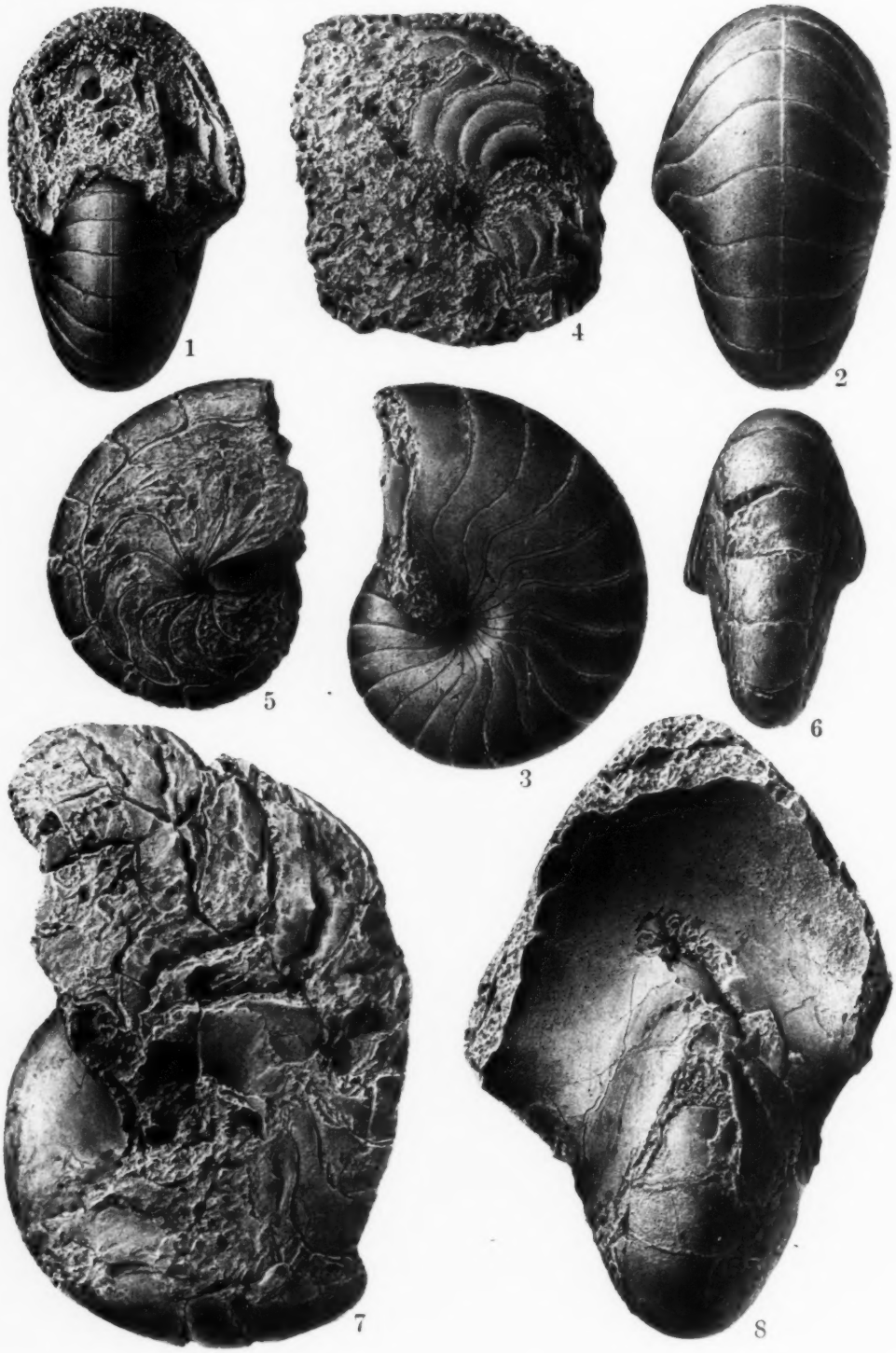
5, 6—*Aturia* cf. *A. myrlae* Hanna. A small specimen, from the Eocene Arroyo Hondo formation north of Coalinga, California, ×3. (p. 15)

7—*Cimomia?* sp. A fragment of a moderately small conch of uncertain affinities, from a limestone bed in a brown Paleocene shale about 12 km. northeast of Hato Nuevo, Departamento de Magdalena, Colombia, ×2. (p. 5)

8—*Aturia angustata* (Conrad)? An incomplete internal mold, from the Miocene Temblor formation in Kern County, California, probably near Mt. Poso oil field, ×1. (p. 9)



Miller and Downs, Tertiary nautiloids



Miller and Downs, Tertiary nautiloids

Remarks.—This specimen is the first nautiloid to be recorded from the Paleocene of Baja California. The matrix in which it is preserved is a dark-gray fine-grained calcareous sandstone. In the filling of the living chamber there are several types of small gastropods, one of which, according to W. P. Popenoe, appears to be *Retipirula crassitesta* Gabb.

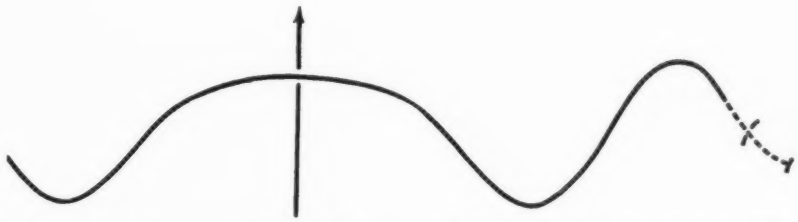


FIG. *1*—Diagrammatic representation of an external suture of *Hercoglossa popenoei* M. & D., n. sp., based on the adoral sutures of the holotype, ×½.

The new species is a typical representative of the genus *Hercoglossa*. It is close to the genotype, *H. orbiculata* (Tuomey), and to *H. mcglameryae* Miller and Thompson, both of the Midway group of the Gulf Coastal Plain—in the former the conch is relatively wide and in the latter relatively small and narrow. Other similar species are *H. merriami* Dickerson of the Martinez formation of California in which the lateral lobes of the sutures are deeper and more narrowly rounded, *H. gardneri* Stenzel of the Kincaid formation of Texas in which the ventral lobe of the sutures is more nearly straight-sided, and *H. peruviana* Berry of the Talara formation of Peru which has a wider conch.

Occurrence.—From concretion in fine-grained gray sandstone of Paleocene age cropping out a few feet below the base of the Tertiary lava beds capping the interstream divides, in sea cliff on south side of valley of Arroyo Santa Catarina, about 200 feet above sea level and perhaps an eighth of a mile inland at unnamed point about 2½ miles northwest of Punta Canoas, Santa Catarina Landing, Baja California (U. C. L. A. loc. 2372).

Holotype.—University of California, Los Angeles, 10655.

DELTOIDONAUTILUS HAUGHTI (Olsson)
Plate 4, figures 1–3, 7, 8

Eutrephoceras haughti OLSSON, 1928, Bull. Am. Paleontology, vol. 14, no. 52, p. 101, pl. 23, fig. 2; MAURY, 1930, Serv. geol. e min. Brasil, Mon., no. 8, pp. 249, 250.

Cimomia haughti MILLER and THOMPSON, 1933, Jour. Paleontology, vol. 7, p. 305; MILLER, 1947, Geol. Soc. America, Mem. 23, pp. 6, 10, 42–43, 45, 46, pl. 16, figs. 1, 2; pl. 64, fig. 3.

Professor Bernardo Boit of the Universidad de San Marcos kindly sent in for study 14 nautiloids that Sr. Pedro Verástegui M. had collected from the Lomitos sandstone at a single locality near Cabo Blanco in northwestern Peru. Eleven of these appear to represent one species, though they vary in diameter from about 39 mm. (pl. 4, figs. 1–3) to approximately 172 mm. (pl. 4, figs. 7, 8). The smaller ones seem to resemble

EXPLANATION OF PLATE 4

FIGS. *1–3*—*Deltoidonautilus haughti* (Olsson). A small well preserved internal mold (representing the adolescent portion of the conch), from the Eocene Lomitos sandstone at Cerro Organos, 6 miles northeast of Cabo Blanco, Provincia de Paita, Departamento de Piura, Peru, ×1½. (p. 7)

4—*Aturia* sp. A small specimen, from the lower Miocene on the south side of the mouth of Wadi Gharandel some 2 or 3 miles north of Hammam Faraun, Sinai, ×2. (p. 17)

5, 6—*Aturia peruviana* Olsson. A small internal mold from the same horizon and locality as figures *1–3*, ×1½. (p. 14)

7, 8—*Deltoidonautilus haughti* (Olsson). An internal mold of a large mature phragmacone, from the same horizon and locality as figures *1–3*, ×1½. (p. 7)

in all significant particulars the holotype of *Eutrephoceras* [*Cimomia*] *haughti* Olsson, which came from the Talara formation at a nearby locality in northwestern Peru and which is therefore of about the same age. However, the larger individuals possess all of the characteristics of the genus *Deltoidonautilus*, and the intermediate ones are gradational between these two extremes. It therefore seems to us that almost certainly Olsson's species was based on an adolescent specimen, the fully mature portion of which would have revealed that its generic affinities are with *Deltoidonautilus*. In view of the fact that this genus is believed to have evolved from *Eutrephoceras* through *Cimomia*, it is not surprising that the inner volutions of its conch resemble those of mature representatives of these genera.

The material now available for study shows that the phragmacone of this specie attained a diameter of at least 172 mm., and a corresponding height and width of conch of some 115 mm. and 120 mm., respectively. At full maturity, the ventral zone of the conch becomes so narrowly rounded as to be almost subangular, the lateral zones are greatly flattened and converged ventrally, and therefore the volutions are subtriangular in cross section, dorsal impressed zone disregarded. Only the adoral half volution of our largest specimens (for example, pl. 4, figs. 7, 8) have this more or less deltoid cross section, for the rest of the conch is not as narrowly rounded ventrally or as strongly flattened laterally. The living chamber attains a length of more than half a volution.

The umbilicus is small but moderately prominent, and the umbilical shoulders are fairly distinct. The test seems to be of about average thickness except in the region of the umbilicus where it is greatly thickened to form a callus. Its surface is marked by numerous very fine faint transverse lines which form broad rounded lateral salients and a moderately deep ventral sinus. On well preserved internal molds, there is a rather prominent raised line along the venter (pl. 4, figs. 1, 2).

At full maturity, each suture forms a high very narrowly rounded ventral saddle, and on either side of it a rather deep broadly rounded lateral lobe, a smaller prominent saddle which centers well outside the umbilical shoulder, apparently a lobe on the umbilical wall, and a broad rounded internal lateral saddle, which extends to a rather deep narrowly rounded dorsal lobe. The sinuosity of the sutures seems to increase progressively throughout ontogenetic development. The fact that the shape of the sutures changes rapidly in the outer volution of the small specimen represented by figures 1–3 on plate 4, indicates that it represents only the immature portion of the conch.

The siphuncle is moderately small and is located fairly close to the dorsum. Where the conch is about 53 mm. high and is impressed to a depth of about 23 mm., the siphuncle is about 4 mm. in diameter and its center is about 8 mm. from the dorsum and 22 mm. from the venter.

Remarks.—In both the holotype and the small specimen which Miller (1947, p. 43, pl. 16, figs. 1, 2) doubtfully associated with it, the siphuncle is also dorsad in position. In the genotype of *Deltoidonautilus* it is similarly located, but its position in the genotype of *Cimomia* is unfortunately not known. Nevertheless it seems probable that the dorsad position of the siphuncle is one of the best ways to distinguish immature equal-sized specimens of *Cimomia* and *Hercoglossa*.

It should perhaps be mentioned that the genus *Deltoidonautilus* has not been recognized previously in South America. Only one representative of it is so far known from North America, *D. elliotti* Stenzel of the middle Eocene Reklaw formation of Texas. That species seems to be very close to the one under consideration, and, like it, is a rather primitive form of the genus. The specimen described below, which is also from northwestern Peru seems to be an immature representative of a more advanced form.

Occurrence.—All 11 of the specimens in the collection under consideration came from the Lomitos sandstone (which until recently was regarded as a member of the Talara shale) at Cerro Organos, about 6 miles northeast of Cabo Blanco, Provincia de Paita, Departamento de Piura, Peru. The holotype is from the Talara formation at a nearby locality in northwestern Peru, that is, near Lagunitas, Piura; and the

specimen, mentioned above, which Miller questionably associated with it, came from the same formation at a nearby locality.

Repository.—State University of Iowa, 9537 (pl. 4, figs. 1–3, 7, 8) and 9538 (9 unfigured specimens).

DELTOIDONAUTILUS sp.
Plate 10, figures 1–3

Through the courtesy of Dr. A. Myra Keen and Sr. Pedro Verástegui M., we were loaned for study a small representative of *Deltoidonautilus* from the lower Eocene Salina formation of northwestern Peru—its generic affinities had already been recognized by Sr. Verástegui. This specimen is a well preserved completely septate internal mold that is only about 23 mm. in diameter. Near the adapical end of its outer volution, the conch is rather narrowly rounded ventrally and is much wider than high. However, adorally its ventral zone is progressively narrowed and gradually becomes subangular, and the conch increases in height more rapidly than in width. At the adoral end of the specimen, the width and height of conch measure about $15\frac{1}{2}$ and $14\frac{1}{2}$ mm., respectively. The maximum width is attained at or just outside the umbilical shoulders, which are fairly distinct. The umbilicus is small and apparently open but not perforate.

A small portion of the test (or rather a replacement of it) is preserved in one of the umbilical depressions. It shows that the test is quite thin. No trace of growth lines can be discerned on the specimen.

The camerae are rather long, but they become progressively shorter orad. In the adapical half of the outer volution of this specimen there are only about five camerae, whereas there are eight in the adoral half of the same volution.

On the adapical portion of the outer volution, the external sutures are essentially straight and directly transverse, though they seem to form an incipient ventral saddle. Throughout the length of that volution this saddle becomes higher. Also, umbilical saddles are developed in the outer volution, and they increase in prominence relatively rapidly. As a result, the adoral suture of this specimen consists of a low broad subangular ventral saddle and on either side of it a shallow broad rounded lateral lobe, a small but rather prominent very narrowly rounded umbilical saddle, a small rounded lobe on the umbilical wall, and apparently a slight internal lateral saddle which extends to a similar dorsal lobe.

The siphuncle is small and is dorsal but not quite marginal in position. At the adoral end of the specimen, it is almost 1 mm. in diameter and is about half a millimeter from the dorsum.

Remarks.—As a result of its small size and particularly because the form of the conch and the shape of the sutures change rapidly throughout the length of the outer volution, we believe that this specimen represents only the immature inner portion of a conch. However, its generic affinities are almost certainly with *Deltoidonautilus*, and it appears to be a rather well developed representative of that genus. That is, in spite of its small size and presumed immaturity, its ventral zone is subangular, and in that respect it is farther advanced than is *D. haughti* (Olsson) at full maturity. Nevertheless, the beds which carry that species are considerably younger than are those which yielded the specimen under consideration.

Occurrence.—This specimen was secured by Sr. Pedro Verástegui M. from the lower Eocene Salina formation south of the village of Yasila, Provincia de Paita, Departamento de Piura, Peru (approximately at latitude 5° 08′ S. and longitude 81° 10′ E.).

Repository.—Stanford University.

ATURIA ANGUSTATA (Conrad)?
Plate 1, figures 6–8; Plate 3 figure 8; Plate 9, figures 1, 2

The collections of the University of California at Berkeley contain four specimens which are probably referable to this species and which have not been mentioned in the literature. These were made available to us for study by Professor J. Wyatt Durham.

The one illustrated by figures 6 and 7 on plate 1 represents only the inner volutions of the phragmacone. Its maximum diameter is about 24 mm., and the maximum width of the preserved portion of its conch measures about 12 mm. This specimen shows

that during rather early ontogenetic development, the conch is relatively wide, the sutures are moderately far apart, and the lateral lobes of the sutures are bluntly pointed and are not in contact with the preceding suture. It was found by Professor Durham in the upper Oligocene Twin Rivers formation about an eighth of a mile east of the city of Twin Rivers on the coast of the Straits of Juan de Fuca, Clallam County, Washington (locality A3678 of Durham, 1944, p. 131).

The individual illustrated by figure 8 on the same plate is from the same formation at a nearby locality, that is, in a sea cliff inshore from conglomerate and shale on the beach just east of the first Geodetic Survey mark east of the mouth of East Twin River, Clallam County, Washington. This specimen is very incomplete, and it is not at all well preserved. It is septate throughout, and its maximum diameter measures about 62 mm. In the adapical portion of the outer volution, the shape of the lateral lobes of the sutures can be seen quite clearly.

Figures 1 and 2 on plate 9 represent a well preserved early mature portion of a phragmacone that Professor Durham secured from a nodule in the upper Oligocene Blakeley formation at Bean Point on Bainbridge Island, Washington (Univ. Calif. loc. C-X-3). The maximum diameter of this specimen is about 36 mm., and near its adoral end its conch is about 17 mm. wide and 22 mm. high. Attention should perhaps be called to the fact that the conch is rather broadly rounded ventrally, and the lateral lobes of the sutures, which are pointed, are in contact with the preceding sutures. Portions of the test which are preserved show that its surface is marked by numerous fine but quite distinct growth lines which form broad rounded lateral salients that extend from a presumed hyponomic sinus clear to the umbilicus.

The other specimen that we are illustrating (pl. 3, fig. 8) and referring to this species is from the Miocene Temblor formation at some unrecorded locality in Kern County, California, probably near the Mt. Poso oil field. The adoral portion of this specimen is essentially free from distortion and represents the complete circumference of the conch. Near its adoral end, the maximum height and width of conch measure about 57 mm. and 37 mm., respectively. As shown by the accompanying figure, the shape of the sutures is also elucidated by this portion of the specimen.

Remarks.—Miller (1947, pp. 85–88) has recently published the extensive synonymy of this species and a detailed discussion of it. Inasmuch as his report is readily available, there is no need for us to duplicate his work.

Occurrence.—This species is known to range from the middle (lower?) Oligocene to the middle Miocene in the Coast Ranges of Washington, Oregon, and California, where it has been found at many localities. The precise horizon and locality of each of the specimens discussed above is given in the preceding paragraphs.

Repository.—University of California, Berkeley.

Aturia brazoensis Stenzel
Plate 9, figures 5, 6

Miss Julia Gardner recently sent us for study a fine representative of the genus *Aturia* that was found April 16, 1941, in the lower portion of the Claiborne group in East Texas. It is a well preserved internal mold that is completely septate. Its maximum diameter measures about 104 mm., and the portion of its conch that is represented attained a maximum height of about 67 mm. and a corresponding width of a little more than 50 mm. (estimated). Its general physiognomy and the nature of its umbilicus, septa, etc. are elucidated by the accompanying photographs.

This specimen is of almost exactly the same size, shape, and proportions as the holotype of *A. brazoensis* Stenzel (a testiferous specimen), and there is no doubt in our

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Explanation of Plate 5

Figs. *1, 2*—*Hercoglossa popenoei* M. & D., n. sp. Ventral and lateral views of the holotype, from a dark-gray calcareous Paleocene sandstone about 2½ miles northwest of Punta Canoas, Baja California, very slightly less than ×1½. (p. 6)

2

1

Miller and Downs, Tertiary nautiloids

2

1

Miller and Downs, Tertiary nautiloids

mind that the two are conspecific. That species has previously been found to occur at several horizons and localities in the Eocene Claiborne group, that is, in the Stone City beds of central Texas, the Tyus and Viesca members of the Weches formation of central and east Texas, and possibly the Cook Mountain formation of south Texas. Miller (1947, pp. 88–90, pl. 69, figs. 1–4; pl. 70, figs. 1, 2; pl. 71, figs. 1, 2; pl. 72, figs. 6, 7; pl. 73, fig. 7) has recently discussed the species in detail and listed its complete synonymy.

Occurrence.—"Probably rather low in the Claiborne group" on the east side of the Chireno road directly south of the San Augustine-Nacogdoches highway, Nacogdoches County, Texas.

Repository.—U. S. National Museum.

ATURIA CUBAENSIS (Lea)
Plate 9, figures 3, 4

Nautilius Cubaensis LEA, 1841, Am. Phil. Soc., Tr., n. ser., vol. 7, p. 259, pl. 10, fig. 15.
(?) *Aturia zig-zag* SALTERAIN, 1880, Bol. Com. Mapa geol. España, t. 7, p. 198.
Aturia cubaensis MILLER, 1947, Geol. Soc. America, Mem. 23, pp. 7, 8, 10, 92, pl. 83, figs. 4–6.

All that Miller was able to ascertain in regard to the derivation of the holotype of this species is that it was obtained long ago by Louis Vanuxem from a "white limestone of Matanzas," Cuba. Dr. Pedro J. Bermúdez who is thoroughly familiar with the geology of Cuba, and particularly that of the Matanzas area, has recently written us that in "the vicinity of Matanzas city there is a good exposition of Tertiary sediments with beds of lower Eocene, upper Oligocene, Miocene, and Pliocene. The locality most visited by geologists and fossil collectors is the Yumurí Gorge very close to the city. In this place the river cuts the sediments very deeply. The Tertiary is well exposed in this cut" and consists of the following formations: Universidad radiolarian earth (lower Eocene), Cojímar marl (upper Oligocene), Güines limestone (lower Miocene), Canímar marly limestone (middle Miocene), El Abra sandstone and conglomerate (upper Miocene), and Matanzas marly limestone (Pliocene). "In this section the only beds which really are of limestone belong to the lower Miocene, Güines formation This cavernous limestone is characterized by the abundance of macrofossils but shows very poor conditions of preservation. Below this limestone there is a good marl formation (upper Oligocene, Cojímar formation) with abundant microfauna. It is possible that the type locality of *Aturia cubaensis* is in the Güines formation rather than in the Cojímar formation."

Dr. Bermúdez also kindly loaned us for study a portion of an internal mold of a phragmacone of an *Aturia* which many years ago was given to him by a friend who lives in Matanzas and who informed him that it came from "the Güines limestone, exposed in the Yumurí Gorge of Matanzas." He adds that its presevation is "very similar to the fossils of the Güines formation." This specimen, like the holotype of *A. cubaensis*, is preserved in "hard fine-grained white limestone," and the two most probably came from the same formation and represent only one species. However, Dr. Bermúdez's specimen is somewhat crushed, and its proportions can therefore not be determined accurately. Its general physiognomy and the shape of its sutures are elucidated by the accompanying figures. It should perhaps be stated that the maximum height of the portion of the conch that is represented measures about 41 mm., and no trace of any markings other than the sutures can be discerned on the specimen.

Furthermore, Dr. Bermúdez called our attention to the fact that in 1880 Salterain had listed "*Aturia zig-zag* (Sow.)" from Cantera (quarry) La Criolla, Habana, Cuba. According to Dr. Bermúdez, the age of the beds exposed at "this locality is upper Oligocene and lower Miocene." This form may therefore well be referable to *A. cubaensis*.

It should also be mentioned in this con-

EXPLANATION OF PLATE 6

FIGS. *1, 2*—*Hercoglossa peruviana* Berry. Lateral and ventral views of a large completely septate individual, from the Eocene Talara formation near Lobitos, Peru, ×⅔. Same specimen as figure *2* on plate 7. (p. 5)

nection that Mrs. Katherine V. W. Palmer has written us that in one of the notebooks of the late Dorothy K. Palmer, the genus *Aturia* is stated to be represented in the type section of the Jicotea, that is, in "gray lime ss., side of Carretera Central in Jicotea," Provincia Santa Clara, Cuba (Palmer, R. H., 1948, p. 12—locality 114). According to Bermúdez (1938) the age of the Jicotea is middle Eocene, and its type section has yielded *Globorotalia centralis* Cushman and Bermúdez, which Mrs. Dorothy K. Palmer considered characteristic of that age. It is therefore rather doubtful that this form is very closely related to *A. cubaensis*, which presumably is typical of much younger beds.

Occurrence.—Güines limestone (Lower Miocene) in the Yumurí Gorge near Matanzas, Cuba.

Repository.—Private collection of Dr. Pedro J. Bermúdez of Caracas, Venezuela.

ATURIA CURVILINEATA Miller and Thompson
Plate 10, figures 4–7

(?) *Nautilus* (fragments) MAURY, 1902, Bull. Am. Paleontology, vol. 3, no. 15, p. 60 (370).
Aturia curvilineata MILLER and THOMPSON, 1937, Eclogae geol. Helvetiae, vol. 30, pp. 61, 69–70, pl. 9, figs. 1–4; pl. 10, figs. 1, 2; MILLER and FURNISH, 1938, Jour. Paleontology, vol. 12, pp. 150, 151, fig. 1G; MILLER, 1947, Geol. Soc. America, Mem. 23, pp. 7, 10, 11, 40, 86, 93–94, 106, 110, 111, pl. 73, figs. 3, 4; pl. 84, figs. 1, 2, 5–8; pl. 85, figs. 4–6.
Aturia sp. MILLER, 1947, Geol. Soc. America, Mem. 23, pp. 7, 8, 110–111, pl. 88, figs. 2, 3.

Two exquisite but slightly broken aturias were recently collected from the Miocene of Florida by Mr. Chas. R. Locklin and sent to Miss Julia Gardner, who kindly forwarded them to us for study. Both are testiferous and are septate throughout.

The maximum diameter of the more nearly complete individual (pl. 10, figs. 4, 5) measures about 54 mm., and the corresponding height and width of its conch are approximately 37 mm. and 21½ mm., respectively. The maximum width of conch is attained just outside the umbilical shoulders, the lateral zones are almost flat and are distinctly converged ventrad, and the ventral zone is rather narrowly rounded. The umbilicus is small and inconspicuous, and the umbilical shoulders are low, rounded, and indefinite.

The test, which in both of the specimens under consideration is iridescent, is thin except in the umbilical region where it forms a callus. Its surface is marked by numerous fine but very distinct growth lines, each of which forms a deep narrowly rounded ventral sinus and on either side of it a broad rounded lateral salient which extends clear to the umbilicus.

The sutures are not well exposed, but they do not seem to differ in any available particular from those of other representatives of this species. The spacing of the septa also is typical of the species.

The specimen represented by figures 6 and 7 on plate 10 (the preserved portion of which is about 55 mm. in diameter) reveals the siphuncle particularly well. It is located close to the dorsum in adapical infundibular inflections of the septa which are telescoped to a considerable extent.

Remarks.—Clearly these two specimens are specifically identical with the similar but somewhat smaller one from the same general horizon and locality described and illustrated by Miller in 1947 as "*Aturia* sp." Also, as noted by that author, it is quite likely that the specimens which in 1902 Maury listed as "*Nautilus* (fragments)" are conspecific, but they seem to have been lost.

However, the relationship of the Floridian specimens to those from South America that have been referred to this species is not quite as certain. The holotype, which came from the Miocene of northwestern Venezuela, is relatively large and is somewhat distorted and laterally compressed, but other Miocene South American specimens (from the same and different localities) have slightly but distinctly narrower conchs. Opinions of various authors in regard to the taxonomic value of such variations differ, but we are inclined to believe that for the present, at least, they should not be regarded as of sufficient importance to justify specific separation.

Occurrence.—Both of the specimens we are studying came from the lower part of the Miocene Chipola formation at Ten Mile Creek on the Chipola River, about 18 miles south of Marian and 2 miles west of the McCelland farm, Calhoun County, Florida.

The specimen which Miller described and illustrated in 1947 came from the same formation at or near the same locality, whereas those listed by Maury in 1902 were from Bailey's Ferry, also in Calhoun County, Florida. In South America, specimens that are tentatively being regarded as conspecific are known from the Miocene of Venezuela, Trinidad, and Ecuador.

Figured Specimens.—U. S. National Museum and The Academy of Natural Sciences of Philadelphia.

ATURIA cf. A. GRANDIOR Schenck
Plate 7, figure 1; Plate 8, figures 1, 2

The collections of the University of California at Berkeley contain seven specimens that may belong in this species, and Professor J. Wyatt Durham kindly loaned them for study. Two of them merit illustration and all seven at least brief description.

The largest (pl. 7, fig.1) is unfortunately somewhat crushed, but it appears to be essentially complete. It is testiferous and, except in size, seems to resemble the holotype rather closely so that the two may well be conspecific, though this one came from the Eocene Cowlitz formation whereas the type is from an Oligocene tuff—both were found in western Washington. The maximum diameter of this specimen, in its present crushed state, is about 235 mm.—that of the holotype is about 160 mm. Because of the distortion which the conch has undergone other measurements would have little significance. As in the holotype, the living chamber is a little more than half a volution in length, and the surface of the test is marked by fine but very distinct growth lines each of which forms a deep ventral sinus and on either side of it a broad rounded lateral salient that extends to the umbilicus. In the adoral portion of this specimen the test is approximately 1 mm. thick, except in the umbilical region, where it forms a callus. The shape of the adoral sutures is revealed, and they do not seem to differ materially from those of the holotype.

The lower Oligocene Keasey shale (or its stratigraphic equivalent) in northwestern Oregon has also yielded a specimen which may be related to the holotype of this species. However, it represents only the umbilical and lateral portions of a little more than half of one side of a volution of a phragmacone (and the crushed inner whorls) and it is so distorted and fragmentary that its specific affinities are very uncertain. The preserved portion of this incomplete specimen is estimated to have attained a diameter of some 150 mm. The lateral lobes of the sutures are asymmetrically attenuate, and at least these lobes and the lateral saddles are very similar to those of the holotype.

The collections under consideration also contain three large fragmentary specimens from the equivalent of the Keasey in southwestern Washington. None of these is sufficiently well preserved or nearly enough complete to be identified specifically, but all three appear to represent portions of phragmacones of the same general size and proportions as typical *A. grandior*. We are therefore comparing them with that species.

The specimen illustrated by figures 1 and 2 on plate 8 is from the Oligocene Quimper sandstone of northwestern Washington. It is primarily an internal mold of the outer volution of a moderately large specimen, but considerable portions of the test adhere to it. The adoral part of this specimen represents living chamber. The phragmacone attained a maximum height of conch of about 95 mm., and the corresponding width of conch and over all diameter are estimated to have been 65 mm. and 150 mm., respectively. The lateral zones of the whorl are strongly flattened and are distinctly converged ventrad, and the maximum width of conch is therefore attained slightly ventrad of the low rounded indefinite umbilical shoulders. The ventral zone of the conch is rather broadly and evenly rounded. The umbilicus is small and inconspicuous and seems to be filled with a callus—elsewhere the test is less than 1 mm. thick. The shape of the sutures is elucidated by the accompanying illustrations, and they seem to be essentially the same as those of the holotype. All in all, we believe that this specimen can be referred to *A. grandior* with a reasonable degree of assurance.

The remaining specimen that we are associating with this species is from the Oligocene Lincoln "formation" on Marrowstone Island of northwestern Washington.

It represents about a quarter of each of two successive volutions of a phragmacone which is estimated to have attained a diameter of more than 200 mm. The test (or rather a replacement of it) of the outer volution of this specimen is crushed and is broken into a number of fragments, but it appears to be very thick. The preserved part of the penultimate volution (unlike that of the outer volution) is largely free from distortion, and it shows that the cross section of the conch and the size and position of the siphuncle are essentially the same as in typical representatives of this species. Nevertheless, this specimen is so crushed and fragmentary that its specific affinities are uncertain.

Remarks.—Miller (1947, pp. 97–98, pl. 93, fig. 5; pl. 94, figs. 1, 2) has recently published a detailed description and illustrations of the type specimens of this species, together with a synonymy, and since his work is readily available there is no need to duplicate it. However, attention should be called to the fact that he did not note that Durham (1944, pp. 120, 121 ,192) had referred to the species three (or more) specimens from the Oligocene of northwestern Washington—two of these are described above.

Occurrence.—The seven specimens under consideration are from the following horizons and localities: (1) Cowlitz formation (upper Eocene) on Olequah Creek, just below the falls and above the grits, Lewis County, Washington (presumably equivalent to Univ. Washington loc. 301); (2) Keasey shale, or its equivalent, (lower Oligocene) in south bank of Rock Creek just west of highway and railroad bridges (which are side-by-side), 1.9 miles east of Keasey post office and 0.2 mile west of Tara station, Colombia County, Oregon; (3) Keasey equivalent in bluff on north side of bend in Willapa River about half a mile east of Holcomb, Pacific County, Washington (two large fragmentary specimens); (4) Keasey equivalent in high bluff along Willapa River at Big Bend about $1\frac{1}{4}$ miles due north of Hanan foot bridge across river north of Holcomb, Pacific County, Washington (loc. A64 of Durham, 1944, p. 130); (5) concretion in *Molopophorus gabbi* zone of Quimper sandstone (lower Oligocene) along beach close to Willamette Meridian line, center $NE\frac{1}{4}$ $SE\frac{1}{4}$ sec. 1, T. 29 N., R. 1 W., Jefferson County, Washington (loc. A3702 of Durham 1944, p. 132); and (6) *Turritella porterensis* zone of Lincoln "formation" (middle Oligocene), 100 feet stratigraphically below sandy shales of Marrowstone shale in sea cliff, center $NE\frac{1}{4}$ sec. 32, T. 30 N., R. 1 E., Marrowstone Island, Jefferson County, Washington (loc. A3696 of Durham, 1944, p. 132). Durham (1944, p. 121) indicates that this species also occurs in the *Turritella porterensis* zone of the Marrowstone shale (middle Oligocene) in the $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 32, T. 30 N., R. 1 E., Marrowstone Island (loc. A3695 of Durham, 1944 p. 132). Both the holotype and the paratype came from the Oligocene of western Washington.

Repository.—University of California, Berkeley.

Aturia peruviana Olsson
Plate 4, figures 5, 6

A collection of cephalopods made by Sr. Pedro Verástegui M. at Cerro Organos, near Cabo Blanco in northwestern Peru, and sent to us by Professor Bernardo Boit of the Universidad de San Marcos contains three small completely septate internal molds that are most probably referable to this species. All of these are of about the same general size. The best one is represented by figures 5 and 6 on plate 4. It is about $32\frac{1}{2}$ mm. in diameter and near its adoral end, its conch is about 20 mm. high and 18 mm. wide. The maximum diameter of the other two specimens measures about 33 mm. and 35

Explanation of Plate 7

Fig. *1*—*Aturia* cf. *A. grandior* Schenck. An essentially complete crushed testiferous individual, from the Eocene Cowlitz formation just below the falls and above the grits on Olequah Creek, Lewis County, Washington, $\times\frac{1}{2}$. (p. 13)

2—*Hercoglossa peruviana* Berry. Apertural view of a large completely septate individual, from the Eocene Talara formation near Lobitos, Peru, $\times\frac{3}{5}$. Same specimen as figures *1* and *2* on plate 6. (p. 5)

2

1

Miller and Downs, Tertiary nautiloids

2

1

Miller and Downs, Tertiary nautiloids

mm. The general physiognomy of the conch and the nature of the sutures are elucidated by the accompanying illustrations.

Remarks.—These three specimens are of about the same size and shape as one from the same general horizon and locality that was figured by Miller (1947, pl. 83, figs. 1–3). A direct comparison of it with those now under consideration leaves no doubt in our mind that all four are conspecific. Miller's report, which is readily available, contains a detailed description and a complete synonymy of this species.

Occurrence.—All three of the specimens we are studying were found in association with *Deltoidonautilus haughti* (Olsson) in the Lomitos sandstone at Cerro Organos, 6 miles northeast of Cabo Blanco, Provincia de Paita, Departamento de Piura, Peru. This species, as now interpreted, also occurs in the upper Eocene Saman formation in the same general region and in the upper Eocene of southwestern Ecuador?, Panama, northern Colombia, and northwestern Venezuela. Furthermore, some of the paratypes of it came from the Oligocene of northwestern Peru, and the middle Eocene of that area has yielded a single small immature specimen that is probably conspecific.

Repository.—State University of Iowa, 9539 (pl. 4, figs. 5, 6) and 9540 (2 unfigured specimens).

ATURIA spp.
Plate 1, figure 9; Plate 3, figures 1, 2, 5, 6

The collections under consideration contain a few Pacific Coast Eocene aturias of which we are unable to determine the specific affinities. These came from two localities in California and one in Washington, and they were loaned to us for study by Professor J. Wyatt Durham.

One of them (pl. 1, fig. 9) is from the Crescent formation of northwestern Washington. It is a rather poorly preserved testiferous specimen which is about 54 mm. in diameter. It appears to have been slightly crushed and flattened laterally, but its present maximum width measures about 20 mm. It is rather narrowly rounded ventrally, and its flattened lateral zones converge ventrad rather strongly. The surface of its test is marked by numerous fine growth lines, each of which forms a deep narrowly rounded ventral sinus and on either side of it a broad rounded lateral salient which extends clear to the closed umbilicus. Only small portions of the sutures are visible, but they do not seem to differ materially from those of similar congeneric forms. This specimen came from a black fine-grained sandstone layer (with abundant *Loxotrema*) about 16 to 20 feet stratigraphically below the contact with the basalt, in the Eocene Crescent formation near the base of the sea cliff on a small point about 250 yards west of the beacon shown on the west side of Crescent Bay on the Port Crescent quadrangle, Clallam County, Washington.

At one locality, the Vacaville shale of central California has yielded three aturias that are crushed and rather poorly preserved. Presumably all are conspecific, but their preservation leaves so much to be desired that we are uncertain in regard to their precise affinities. All are internal molds that are largely septate. The best one is represented by figures 1 and 2 on plate 3. One of the others seems to represent a slightly larger individual, whereas the third is only a very small segment of a phragmacone of uncertain size. Because of the distortion which all three of these have undergone, precise measurements of them would have little significance. The spacing and the shape of their sutures, and particularly the form of the lateral lobes of those sutures (see pl. 3, fig. 1) indicate that this form is a rather primitive representative of the genus. All three of these specimens are from the lower Eocene Vacaville shale member of the Capay formation about half a mile north of "Black Rocks" in Putah Creek, 1280 feet east and 1302 feet north of the southeast corner of sec. 23, T. 8 N., R. 2 W. (Mount Diablo Meridian), Yolo County, California.

EXPLANATION OF PLATE 8

FIGS. *1, 2*—*Aturia grandior* Schenck. Ventral and lateral views of a specimen from a concretion in the Oligocene Quimper sandstone along the beach close to the Willamette Meridian line, center $NE\frac{1}{4}$ $SE\frac{1}{4}$ sec. 1, T. 29 N., R. 1 W., Jefferson County, Washington, $\times\frac{3}{8}$. (p 13)

The specimen represented by figures 5 and 6 on plate 3 is the one from the Arroyo Hondo formation of west-central California that was illustrated and briefly described by Vokes (1939, p. 107, pl. 16, fig. 36). It is a completely septate internal mold which has a maximum diameter of only about 12½ mm. Its small size, and particularly the wide spacing of its septa indicate that it represents only the immature portion of a phragmacone. This belief is strengthened by the fact that the lateral lobes of the sutures are rather bluntly pointed. Vokes states that this specimen was found associated "with abundant fragments of the outer shell of much larger individuals," and he referred it to *Aturia myrlae* Hanna; that identification may well be correct, but it is difficult to substantiate. This specimen came from the Eocene Arroyo Hondo formation in the SW¼ NW¼ sec. 15, T. 18 S., R. 14 E., 100 feet up the fourth small draw from west end of ridge, immediately opposite the place where Urruttia Canyon enters Salt Creek, north of Coalinga, Fresno County, California (Univ. Cal. loc. 1817).

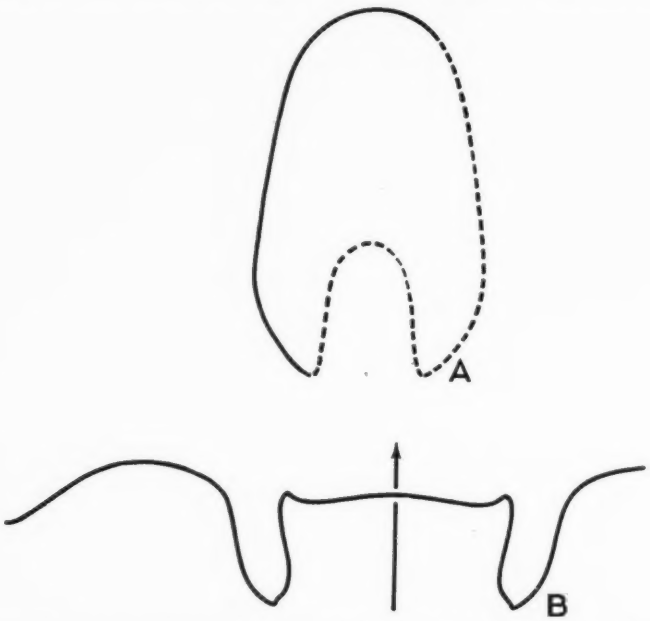

FIG. 2—Diagrammatic cross section and representation of an adoral suture of a small specimen belonging in the genus *Aturia*, from the lower Miocene of the west-central portion of the Sinai Peninsula, both ×4.

Occurrence.—One of the forms described above is from the Crescent formation of northwestern Washington, another is from the Vacaville shale (Capay) of central California, and the third is from the Arroyo Hondo formation of west-central California. The precise horizon and locality is given along with the discussion of each.

EXPLANATION OF PLATE 9

FIGS. *1, 2*—*Aturia angustata* (Conrad)? A small well preserved internal mold, from a nodule in the Oligocene Blakeley formation at Bean Point on Bainbridge Island, Washington, ×2. (p. 9)

3, 4—*Aturia cubaensis* (Lea)? A crushed fragment of an internal mold, from the lower Miocene Güines limestone in the Yumurí Gorge, near Matanzas, Cuba, ×1. (p. 11)

5, 6—*Aturia brazoensis* Stenzel. A well preserved internal mold, from the lower part of the Eocene Claiborne group on the east side of the Chireno road directly south of the San Augustine-Nacogdoches highway, Texas, ×1. (p. 10)

Miller and Downs, Tertiary nautiloids

Miller and Downs, Tertiary nautiloids

Repository.—All are in the paleontological collections of the University of California at Berkeley. The one from the Arroyo Hondo formation is numbered 15877.

APPENDIX

AN ATURIA FROM THE MIOCENE OF SINAI

Through the courtesy of Dr. A. Myra Keen of Stanford University, we were kindly loaned for study a small representative of the genus *Aturia*, which seems to merit special consideration because of the locality from which it came. This specimen was secured in March of 1921 by Mr. Robert van Vleck Anderson from the "lower beds of [the] Miocene series" in a prominent bluff on the south side of the mouth of Wadi Gharandel on the Gulf of Suez coast of Sinai, some two or three miles north of Hammam Faraun. The label which accompanies it shows that it was identified by H. G. Schenck as *Aturia aturi* (Basterot), and it may well be the basis for his indication (Schenck, 1931, map on p. 437) that the genus occurs on this peninsula.

This specimen is partially imbedded in a block of light-colored (white mottled with brown) crystalline limestone which contains some rather poorly preserved gastropods and other small fossils. Its general physiognomy is elucidated by the accompanying illustrations (pl. 4, fig. 4; and text fig. 2); but attention should perhaps be called to the fact that its maximum diameter is only about 23 mm., and therefore we are of the opinion that it represents the adolescent or early mature portion of a conch that was much larger at full maturity. At least its adoral sutures are so closely spaced that the adapical portions ("tips") of the lateral lobes are in contact with the adoral portions (ventrolateral shoulders) of the ventral saddles of the preceding sutures. The lateral lobes of the sutures seem to be rather primitive for a Miocene representative of this genus, which strengthens our conviction that we are not dealing with a fully mature phragmacone.

Although this specimen may well belong in *Aturia aturi*, which was orginally described from the Miocene of France, we hesitate to refer it definitely to any species. It is the property of the Paleontological Museum of Stanford University, where its catalogue number is 7993 (type collection).

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EXPLANATION OF PLATE 10

FIGS. *1–3*—*Deltoidonautilus* sp. A small immature specimen from the Eocene Salina formation south of the village of Yasila, Departamento de Piura, Peru, ×1½. (p. 9)

4–7—*Aturia curvilineata* Miller and Thompson. Two exceptionally well preserved testiferous specimens, from the Miocene Chipola formation at Ten Mile Creek on the Chipola River, Calhoun County, Florida, ×1½. *4*, *5*, USNM specimen. (p. 12)

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SOME NOMENCLATORIAL AND TAXONOMIC PROBLEMS IN PALEOZOOLOGY

WITH A DISCUSSION OF THE CORRELATION OF SOME UPPERMOST JURASSIC AND CRETACEOUS FAUNAS ON BOTH SIDES OF THE ATLANTIC

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ABSTRACT—Some aspects of the prevailing use of generic, specific and infraspecific categories in invertebrate paleozoology and the difficulties arising therefrom are reviewed. The writer criticizes undue multiplication of species and genera in modern paleozoology and seeks to determine the causes. Strict regard for quality and quantity of material, extensive use of open nomenclature and infraspecific categories, abolishing of the current practice of splitting and the introduction of "provisional" new names, and adherence to the International Rules of Nomenclature are recommended as a remedy. In the writer's opinion, new species and genera should be introduced sparingly and after careful consideration. Minor morphological differences between closely related forms should be recognized by using infraspecific categories, non-Linnean names or open nomenclature in most cases. In all doubtful cases no new names should be introduced because new specific or generic names seem too often to be of inferior practical value as compared with well-established old names or even with non-Linnean names attached to the old ones. In this connection the so-called "separatist tendency," very pronounced in modern paleozoology throughout the world, is criticized and held specifically responsible for many of the above difficulties of modern paleozoology.

While recognizing in principle the value of neozoological statistical methods in invertebrate paleozoology, the writer puts his faith in the phylogenetical method and the study of evolutionary trends as a sound foundation for paleozoological taxonomy. The importance of "normal stratigraphic successions" for such research is emphasized.

The writer argues in favor of the considerable or even world-wide horizontal ranges of many fossil species and faunas. Opposite views, very pronounced in modern invertebrate paleozoology, are considered to be incorrect in many instances. Exceedingly dogmatic use of the Lyellian doctrine of uniformity, the "separatist tendency," and other causes discussed above are considered responsible for this theoretical prejudice.

Correlation of some Upper Jurassic and Cretaceous faunas on both sides of the Atlantic is chosen to illustrate the author's views. He contends that the real affinity between these faunas is much greater than the existing lists of specific and generic names would suggest.

INTRODUCTION

SOME aspects of the prevailing use of genus, species and infraspecific categories are reviewed in this paper and some difficulties arising therefrom are pointed out. The bearing of current taxonomic methods on intercontinental stratigraphical correlations and paleogeography receive particular attention. The writer attempts to concentrate mainly on these problems without going into the more general causes of the present quite unsatisfactory situation in paleozoological research. This has already been touched upon by other authors (e.g. Knight, 1947; Colbert, 1947; Weller, 1947, 1948; Newell and Colbert, 1948; Moore, 1948; Borissiak, 1945).

The questions dealt with in this paper are not only of theoretical, but also of great practical interest, because they deal with overspeciation and complication in present paleozoological nomenclature and taxonomy. In the opinion of the writer there is no doubt that the present situation requires concentrated attention and effective contrameasures on the part of all paleozoologists. The importance of the problem is greatly emphasized by the circumstance that it

affects not only paleozoology, but by repercussion biostratigraphy (or stratigraphical paleontology), and the theory of evolution.

These problems are not in themselves new; many of the ideas set forth in this paper have recently been discussed by various authors. Yet it seems worth while to re-examine and summarize some of the opinions recently expressed. The time is favorable for a paper of this kind, for owing to its theoretical and practical importance the whole question of taxonomic treatment in paleozoology is today being critically surveyed, with the avowed purpose of improving procedure and bringing it more in line with methods of neozoology. This is long overdue, for the principles of distinguishing inferior taxonomic units have been long a matter of controversy in paleozoology as well as in neozoology.[1] Great progress in dealing with these categories has, however, been made in neozoology and extensive discussion of this problem is taking place in paleozoology throughout the world (e.g. Arkell and Moy-Thomas, 1940, Bubnoff, 1919; Clark, 1945; Fedotov, 1940; van Hoepen, 1946; Newell, 1948; Passendorfer, 1933; Pavlow, 1901; Rastall, 1943; Richter, 1943; Roger, 1946; Simpson, 1943; Stolley, 1936; Swinnerton 1939, 1940; Trueman, 1924; Weller, 1947). Nevertheless nomenclature and taxonomy still remain very troublesome in both sciences, and are very far from any positive solution as far as paleozoology is concerned.

The bearing of nomenclatorial-taxonomical complications on the problem of broad intercontinental correlation and standardization of younger Mesozoic beds of this continent also deserve attention. American and Eurasian paleozoologists and geologists have considered it in recent important publications (e.g. Arkell 1946, Muller 1941, Muller and Schenck 1943, Leanza 1947 and others).

[1] Paleozoologists tend to use the terms paleontology and neontology when actually meaning only paleozoology and neozoology. This tendency is apt to cause considerable confusion and is especially inconvenient when used in works dealing with taxonomical problems. Since the Rules of Nomenclature in paleozoology and paleobotany (and accordingly in neozoology and neobotany) are independent and differ considerably the writer prefers to use the more precise terms, paleozoology and neozoology, in all cases when not dealing with paleontology (i.e., both paleozoology and paleobotany) in general.

MULTIPLICATION OF SPECIES AND GENERA IN PALEOZOOLOGY

Modern study has tended more and more to refinement in paleozoological nomenclature, marked by sweeping multiplication of species and genera. Paleozoologists are much too liberal in giving new specific and generic names and in splitting the older broader species and genera, resulting in an extremely complicated nomenclature. Examples of extreme splitting are to be found in numerous works, e.g. those of Buckman 1921–27 and Heinz 1932, and it is scarcely necessary to mention further names and paleontological examples, unfortunately plentiful for practically every group of fossils.

The most striking and perhaps indeed the main evil of this splitting is the fact that every new specific or generic name, once introduced, will in accordance with the rules forever be a complication in the nomenclature and taxonomy, and an obstacle to specialists trying to revise a given fossil or group of fossils, or to deal with the whole field of paleozoology or even with any of its major subdivisions. This difficulty is even greater for every paleozoologist or geologist working on the determination of fossils outside of his particular field.

The harmful results of this steady and intense splitting were recognized long ago. Whitfield (1906, p. 131) one of the very best Mesozoic paleozoologists of this continent, complained about it, stating in connection with one case of "lumping" that: "This is so greatly at variance with the modern method of many paleontologists and other workers in natural history as to make it quite remarkable, for the prevailing practice is to put a new name to everything coming from a new locality, both generic and specific, irrespective of what has been done by previous workers." Further in the same paper Whitfield justly and aptly denounced this 'prevailing tendency' stating: "Since writing the above my attention has been called to a later article . . . where the division into species and genera is carried still

further . . . making seven species and referring them to three distinct genera. From the study of their material . . . I can see no valid reason for considering them other than as individual differences of one and the same species . . . I am thoroughly convinced that it is perversion of the principle underlying the science of paleontology and natural history to multiply specific names to so great an extent." The above quoted accusations of Whitfield are still valid, and very recently able and vigorous attacks against the same procedure were made by Weller (1947, pp. 574–75) and Richardson (1948, pp. 369–70). Yet it may be said that the situation has not improved and presents grave and undesirable consequences not only for paleozoologist-biologist and biostratigrapher-geologist (who are very often united in one person), but also for every biologist-evolutionist. It is not an over-statement (Roger, 1946, p. 272) to say that a worker today can hardly hope to master the nomenclature and taxonomy of a single one of the major subdivisions of paleozoology.

Some new names of course are necessary for new and undescribed species and genera that are always found when a fauna new to science is discovered. This, however, should not be accepted as a license to break up and multiply existing species and genera. After all, the establishment of new names is not in itself the goal of zoology. The main task of paleozoologists is not to exaggerate differences *per se*, and so add to the nomenclature, but to discover morphological similarities and affinities, and to establish evolutionary trends. This purpose can best be served by making broad species and recording finer differences under infraspecific categories. A classical example is furnished by a statistical-phylogenetic revision of the genus *Kosmoceras* by Brinkman (1929). The following question has arisen and has been asked many times: Is the growth of complication in the nomenclature and taxonomy really an inevitable result of the progress of our science? Is it natural, and, if it is, are there any practical methods of minimizing possible undesirable results? The Rules and the Commission of Zoological Nomenclature came into being precisely for this purpose, but as Richter (1943, pp. 8–9 et. seq.) rightly complains[2] it is not enough to have good rules, they should be read and followed and not abused. And it is therefore a pity that so many modern paleozoologists, particularly the younger ones, if we have to judge by their results, are obviously completely unaware of the harm they are doing by carelessly introducing invalid new names into paleozoology, and of the ample provision that has been made to avoid this very thing.

For example, it does not seem to be commonly appreciated that "liberality" in introducing new names was neither recommended nor tolerated by the Rules of Nomenclature. The opinion of the Commission added to paragraph 2 of the Rules (see Richter, 1943, p. 56, Art. 2) states plainly that an author who publishes any name as new to science has to prove definitely that it is indeed new. Unless this can be done, Richter (1943, pp. 34–35, 73), like many other taxonomists, suggests the complete avoidance of new names and the labelling of the fossils by other nomenclatorial means. He points out that the whole procedure of open nomenclature has been created for just such cases. Richter (1943, pp. 39–40) says: "Die offene Namengebung verlangt Zuruckhaltung von dem Forscher, der seinen Stoff in gewissenhafter Weise fur

[2] The writer has chosen this most modern edition of the Rules of the Zoological Nomenclature as the constant source of his references to the Rules. This choice has been made not only because Schenck and McMaster (1935) in "Procedure in Taxonomy," usually used by paleozoologists of this continent, is already somewhat out of date, missing many valuable opinions of the Commission rendered after the date of its issue, but also because the work of Richter (1943) is indeed much more than a simple new edition of the Rules. It contains in addition a splendid essay on the development of zoological nomenclature, a critical study of the present situation, and invaluable and extensive comment and criticism on every article of the Rules. In all this, and also in the completeness and lucidity of his comments, it is superior to the other work mentioned. The last, but not the least, advantage of Richter's work is the fact that it was written by a paleozoologist, and accordingly deals more carefully with purely paleozoological aspects of nomenclature than any other edition of the Rules known to the writer. It is unfortunate that this splendid piece of nomenclatorial and taxonomic study is not yet translated into English.

noch nicht reif zur taxonomisch geschlossenen Einreihung erklart. Für ihn ist diese Zeichensprache ein ernstes Mittel, um die noch undeutlichen neuer Erkenntnisse richtig auszuwerten und dennoch das System von dem Ballast sowohl der voreiligen Falsch-Bestimmung wie der totgeborenen Namen freizuhalten." Entirely similar protests have of course been made by many other paleozoologists. Unfortunately and quite incomprehensibly, these appeals, however numerous, still receive comparatively meager attention by paleozoologists.

THE QUALITY OF PALEOZOOLOGICAL MATERIAL AND PROVISIONAL SPECIES AND GENERA

The regretfully widespread 'liberality' of so many paleozoologists in their nomenclatorial and taxonomic practice is unfortunately greatly aggravated by the circumstance that many of them are making quite insufficient allowance for the quality and quantity of their material. New names are being introduced too commonly without any regard to unsatisfactory preservation of the material, its fragmentary character, the small number of specimens available for study, certainty as to the grade of taxonomic value of the characters employed for separation, sufficient knowledge of the amount of infraspecific or infrageneric variation peculiar to the given form or group of forms, age differences, geographical (subspecific or subgeneric) differences, etc. (see pp. 29–34). Even to the all important factor of geologic time too little attention is being paid in many cases. Not infrequently new names are being introduced 'provisionally' for fossils the taxonomic position of which is uncertain and in some instances actually admitted to be so by the author. Some of these authors, without access to good libraries or foreign collections lack the means necessary to determine whether or not they have new species and genera in their material. They appear to consider the introduction of such uncertain, and perhaps invalid, names as only a minor evil. Where such uncertainty exists it is much better to adopt the open nomenclature. If later the existence of new species or genera can be proved, new names can be introduced without any difficulty. Should, on the contrary, some of the above mentioned too-hurriedly, carelessly or even 'provisionally' introduced names become invalid (as happens in such cases) there would be no legal means of eradicating them from the nomenclature and taxonomy. They would always remain there a source of confusion and misunderstanding among students.

It should be obvious to all that too many new specific and generic names have been, and still are being introduced on the basis of single specimens which are merely poorly preserved fragments of scarcely identifiable imprints in the rock. Yet, despite their fragmentary character, poor preservation and even apparent affinity to some already described fossils, they were proclaimed new to science instead of being allowed to remain undetermined or described in the terms of open nomenclature, pending the arrival of more abundant and better preserved material. Even if the material is unique, or has been obtained from some remote and difficultly accessible corner of the world, and accordingly should not be left undescribed in the interest of science, there is no need at all for the investigator to commit himself to giving new taxonomic names to these poor things, and to present later authors, who would be obliged to take these names into account, with obscure riddles about the proper relations, identity, taxonomic position of independence of these forms. How many times earnest efforts and paper could be spared if the authors concerned would only reflect and consult the Rules before introducing new names. Such caution and use of an open nomenclature would result undoubtedly in much less taxonomic confusion and reduce the number of 'incertae sedis' in every subdivision of paleozoology.

INFRASPECIFIC CATEGORIES IN PALEOZOOLOGY

Infraspecific categories have been discussed recently by Clark (1945), Newell (1948) Simpson (1943) and many other investigators.

It is apparent that, even if the paleozoological material is ample both quantitatively and qualitatively for the recognition of morphological differences, there is no justification in giving specific or generic rank to every such paleozoological specimen

or specimens. There are so many known striking differences between infraspecific categories of a single species, as understood by neozoology that the distinctions noted may be of similar nature. Pronounced infraspecific variation may be correlated with relative age, seasonal change (e.g. in the genus *Onchorhynchus* of Salmonidae where all males show very pronounced changes of the head bones and teeth during the mating period, which could be very well preserved in the fossil state), sex, alternation of generations, disease, dwarfing etc. There exist also geographical and ecological races, in addition to normal, individual variation within a single interbreeding population. All of these factors must have been present in ancient as well as in contemporary organisms, and it is apparent that infraspecific variation in fossil organisms should theoretically be greater than in the living ones. For in dealing with animals of the past it is necessary to consider infraspecific variation not only in space but in time (e.g. Arkhangelsky, 1916, pp. V–VI; Fedotov, 1940; Pavlow 1901; Simpson, 1943; Newell, 1948 and others). In paleozoology at least three different kinds of infraspecific variation should be distinguished; firstly, variation within a single contemporary population, which may be called variants (Newell, 1948, pp. 226–228); secondly, contemporary, infraspecific varieties of the same species in adjacent paleogeographical provinces or regions, that is, paleo-subspecies (i.g. Arkhangelsky, 1916, pp. V–VI; Clark, 1945, pp. 160–161); thirdly, infraspecific variation in geological time, that is, the 'mutations' of Waagen (1869) not of de Vries (1901–03).

It is perfectly true that the first category is taxonomically inferior to the second and included in it, since it deals with the parts of a single population while the latter compares populations with one another (e.g. Newell 1948, pp. 226–228). Yet the writer thinks that it should be kept under a separate name at least in paleozoology. Variants may be unimportant in neozoology but in paleozoology they are of particular importance in the understanding of the evolutionary trends. Also they are not artificial but represent natural groups within the population, which in the course of time prevail or on the contrary disappear gradually under the influence of natural selection. As a matter of fact the paleozoologist is more apt to distinguish and to use variants than paleo-subspecies because the contemporaneity of the latter is rather doubtful in too many cases. As to the third category the writer agrees with Simpson (1943, p. 171) that despite the historical priority of the term 'mutation' (Waagen, 1869) over that of geneticists (de Vries, 1901): "The paleozoologists may as well abandon their priority and admit that the geneticists have carried the day and have succeeded in purloining the word." Newell (1948, p. 231) reached the same conclusion. However, the use of any substitute for this term in paleozoology (e.g. "waagenon") should in the writer's opinion be left to some kind of international paleozoological conference rather than to a single scientist.

As noted by Simpson (1943, pp. 168–69) infraspecific categories have been seldom employed in paleozoology, even though proposals for their use have been made by many specialists (e.g. Arkhangelsky, 1916; Clark, 1945; Newell, 1948). One may agree with Clark (1945, p. 161 et. seq.), Newell (1948, pp. 229–231) and other authors that sometimes it is rather difficult to distinguish paleo-subspecies or even variants in imperfect and relatively scarce paleozoological material. However too little real effort has been made by paleozoologists to recognize them.

It may be recalled that in neozoology there has been a pronounced bias to create a great many closely related independent species based upon their geographical distribution. Such tendency is now less operative for most 'species' resulting from it, were, as more material became available and transitional forms between them were discovered, later found to be mere geographical subspecies, or even lesser infraspecific categories (variants). Would it not be well for paleozoology to terminate the current practice of intensive genus- and species-making and 'splitting,' and adopt instead a much more liberal use of infrageneric and infraspecific categories? In the opinion of the writer it is the duty of every paleozoologist to make at least a sincere attempt to distinguish these categories within his

material, however imperfect, before declaring his morphologically different forms to be specifically or even generically new; this has been done already with remarkable success more than once (e.g. in micropaleontology). As shown by Arkell and Moy-Thomas (1940), Brinkmann (1929), Stolley (1936) and other authors the finest taxonomic distinctions could still be recognized in this way without undue nomenclatorial and taxonomic complications. Subspecific and subgeneric names would be less harmful as they can be omitted if desired (e.g. for teaching purposes, for popular use, for field geologists etc.). Other infraspecific categories are non-Linnean and therefore not obligatory taxonomically. Thus the intense splitting of ammonoid genera and species could easily be halted by introducing sections, subsections, and when necessary, subgenera, and by liberal use of infraspecific categories (e.g. Brinkmann, 1929). By this procedure extreme refinement of paleozoological nomenclature and taxonomy would be made possible without making over-fine details and distinctions a 'pest' for every teaching paleozoologist, for every colleague who is unable to spend all his time in the study of a particular group and for every biostratigrapher, geologist, paleogeographer and evolutionist who is entitled to use paleozoological results without being engulfed by an undue flood of names and complexities of nomenclature and taxonomy.

The writer would suggest that it is not sufficient to find out that a given specimen or even a suite of specimens is morphologically distinguishable from all other closely related forms of the same genus or family in order to pronounce them specifically or even generically new. Before doing so the investigator ought to show that these differences do not fall under any infraspecific category discussed above. In the case of contemporary closely allied forms the presence of a distinct break in the transition between them should be proved, otherwise they would be most probably either mere variants within a single population or paleosubspecies.

Much importance is attributed to difference in stratigraphical range as a proof of specific or even generic distinctiveness of the forms concerned.

Most authors would indeed agree that the difference in stratigraphical range, if accompanied by more or less apprehensible morphological differences between the forms concerned, is a sufficient proof of their specific distinctiveness. Yet it should be kept in mind that evolution is a continuous process, as far as we know, without any marked saltations between species or genera. Theoretically therefore one cannot expect the presence of gaps within the evolutionary series of forms. Apparent gaps may be actually due to depositional hiatus, fragmentary fossil record, etc. Thus all 'horizontal' generic, specific or infraspecific boundaries in paleozoology are artificial cuts in uninterrupted 'vertical' evolutionary lines which are intended to serve the practical ends of biostratigraphy and geology. Accordingly (see Brinkmann, 1929; Arkell and Moy-Thomas, 1940) the paleozoologist is guided by practical considerations alone when cutting evolutionary lines. This very circumstance is undoubtedly responsible for the old tendency of so many authors (e.g. Waagen, 1869; Pavlow, 1901, pp. 60–61; Simpson, 1940, pp. 170–177) to introduce a 'vertical classification' into paleozoology. This would be completely independent of and opposed to the 'horizontal' Linnean classification now in common use in both neo- and paleozoology. It might be indeed advisable for paleozoologists to use both classifications together, since it is highly improbable, for the above mentioned practical reasons, that the phylogenetical 'vertical' classification could prevail over the artificial 'horizontal' classification in paleozoology. Anyway, because of the very artificiality of the paleozoological classification now in use it is evident that every student should use species and genera very sparingly. In so far as artificial cuts in the evolutionary series are very useful stratigraphically it may often be pardonable to separate forms on the basis of morphological differences which are relatively less pronounced than those used for differentiating living forms. Yet it is desirable in most instances not to call them species or genera, but to make the most liberal use of infraspecific and infrageneric categories instead, or even to give them non-Linnean names. Numbers or letters would serve practical

ends just as faithfully as Linnean names, and they would involve no additional burden on nomenclature and taxonomy, which is of extreme practical advantage. Trinomial or quadrinomial nomenclature of the kind used by Brinkmann (1929, pp. 236–238) and some other students on this continent and in Europe may be especially recommended. However, as shown above, in paleozoology one is obliged to distinguish strictly between (a) contemporary variants and subspecies and (b) variants in geological time (mutations of Waagen) (see pp. 23–24).

PRACTICAL VALUE OF NEW SPECIES AND GENERA

It should be also stressed that the introduction of numerous new species and genera, apart from its nomenclatorial disadvantage, does not produce any real paleozoological or stratigraphical achievement. In most cases it does not contribute at all to the progress of zoology, phylogeny or related sciences and thus is in many cases undesirable (see p. 20). Indeed, every practical stratigrapher or paleozoologist would find it more useful to deal with an old, well known and admittedly widely distributed 'species' or even with a form described, by means of open nomenclature, as related to any such species, than with a new 'species' having as yet no known stratigraphical range or paleogeographical distribution. Every new species and genus should ideally be introduced by a careful analysis of its affinities and stratigraphic range and described after a study of many specimens from many localities. Otherwise even all 'good' new species and genera remain for a certain period of time after their introduction, merely names, without any paleozoological or stratigraphical importance.

STATISTICAL METHODS IN PALEOZOOLOGY

Neozoological statistical methods were introduced in paleozoology by Wedekind (1916), Bubnoff (1919), Brinkmann (1929) and many other investigators. However, as suggested by Simpson (1943, pp. 151), most paleozoologists used them to some extent in one form or another long before their formal introduction. There is no doubt that statistical methods are apt to give very valuable and representative results in many cases. Yet it would seem to the writer that their taxonomic-phylogenetical value in paleozoology is somewhat over-estimated by the above authors. In any case there seems to be no justification to treat them as a main basis of paleozoological study, as does Brinkmann (1929) in his excellent work. The fact that paleozoology is an historical science, while neozoology is not, leads to many serious doubts about the efficiency of these neozoological methods in paleozoology. At least it should be pointed out that the consideration of the time factor increases tremendously the number of measurements and calculations that must be performed by a paleozoologist to apply statistical methods, as compared with that needed by a neozoologist. While the neozoologist is always concerned with only one population of each form studied, the paleozoologist has to study a great many successive populations of forms continuously developing from one another. This makes the statistical methods in paleozoology extremely slow, complicated and wearisome.

Apart from this, the paleozoological (in any case invertebrate) material is mostly too fragmental and subject to too many uncertain factors as to the environment, posthumous sorting, deformation, etc., to be successfully investigated with statistical methods. Careful study of the extremely painstaking and accurate work of Brinkmann (1929) shows at once how many uncertainties independent of the investigator are involved in his measurements, calculations and their interpretations. It is quite apparent that his results can mostly be interpreted in more than one way. Brinkmann (1929) himself reveals in many cases possible causes of mistakes and resorts to other ways of interpreting his material. It would seem to the writer that in this and in many other cases the amount of labour required for a thorough statistical study of this kind is not fully justified by the results obtained.

PHYLOGENETICAL METHOD AND "PHYLOGENETICAL FIELDS"

The main objection to a preferred use of statistical methods in paleozoology is, how-

ever, the circumstance that the factor of geological time supplies a paleozoologist with a much more convenient historical method of investigating variations of fossil forms both in time and space using taxonomy. It may be referred to as a phylogenetical method.

This method consists in the direct observation of the course of evolution of the given group of fossils in an ascending succession of beds. In its essence this method requires only sufficiently frequent occurrence of fossils in an essentially unbroken sequence of beds, careful stratigraphic collecting of them, and a thorough study of their morphology and their evolutionary development. When all the series of forms of each thin bed are studied in all their characters, and compared with their successors in ascending order, the course of the evolution of the given group becomes apparent without any statistical curves. The phylogenetic relations of the forms studied may be easily enough inferred from their stratigraphical succession and from the presence or absence of continuous or nearly continuous series of intermediate forms between them. Also the instances of homeomorphy due to the discrepancy in the stratigraphic range may thus be revealed; likewise the places where some series of forms are branching out from the main stem. As a very useful auxiliary the study of the ontogeny of all forms (where available) may be used; it helps considerably to close the breaks in the continuity of evolutionary series studied and to establish the affinities between different branches. Usually the drawing together of morphological characters in the evolutionary series is so apparent that it is unnecessary for them to be really continuous. The requirement of material and its preservation are here less rigorous as compared with those necessary for statistical methods, yet the results, in the opinion of the writer, are just as reliable if not so mathematically "objective" and unbiased and to the neozoologist not statistically demonstrable. It is scarcely necessary to mention that the phylogenetic method is incomparably quicker and easier to apply than a statistical one, and that the former will work wherever the latter will. Of course every worker using this phylogenetic method should employ measurements and statistical methods as one of his auxiliaries wherever necessary. In particular it seems to the writer that the numerous and carefully collected and studied material of *Kosmoceras* used by Brinkmann (1929) for his classical statistical-phylogenetical studies could be easily interpreted taxonomically and phylogenetically with the same results in a primary phylogenetic way, using statistics and variation curves only as an auxiliary method.

The numerous recent complaints as to the unreliability and ambiguity of the phylogenetic method seem to be completely unjustified. They merely reflect the fact that the method was often misused by some too eager adepts of it and too far reaching conclusions were drawn from imperfect and scarce material. In particular the value of the ontogeny in revealing the phylogenetical relations of fossil organisms was considerably overestimated. Accordingly the study of ontogeny was raised to an independent method of evolutionary study, while it apparently is a mere auxiliary of the above method, subject to a steady control by the observation of actual evolutionary series in their stratigraphic succession.

The recent fundamental revision of the relations between ontogeny and phylogeny of the animals by Sewertzoff (1931) has shown, however, that the acceleration of the ontogeny with the consequent recapitulation of ancestral characters in the successors is only one of several possible relations between the ontogeny and phylogeny. Yet at the same time Sewertzoff (1931, pp. 266–77) has shown that the mode of recapitulation, which he calls anaboly, is the most widespread, as compared with other modes of phylogeny, which do not show recapitulation of ancestral characters. Thus the study of ontogeny remains a very valuable, if not universal, paleozoological method, the recent research of Upper Paleozoic ammonites by Ruzencev (1939, 1940) providing an example.

Phylogenetic method was probably first introduced by Hilgendorf (1866) and Waagen (1869) and has been used often with remarkable success (e.g. Neumayr and Paul, 1875; Rowe, 1899). Quite recently its effectiveness was proved beyond doubt by

Tripp (1937, 1938, 1940), Schwegler (1938) and Zoch (1940), who employed it extensively in a study of Jurassic belemnites of Southern Germany. And it is noteworthy that all these authors have found statistical methods to be inferior in usefulness. Tripp (1937, p. 184) states: "Anfänglich wurden Grade der Formänderungen in Länge und Winkel gemessen. Es war auch versucht worden, die Ergebnisse in Kurvenbildern auszudrucken. Ich bin aber zu der Ansicht gekommen, dass es die feinste Methode ist, die Anordnung nach dem Augengefühl vorzunehmen. Man muss das Dynamische sehen lernen." Zoch (1940, p. 485) reached the same conclusion, stating: "Auf rechnerische Darstellungen der Formenvariationen wird verzichtet. Es hat sich andererseits auch als wenig fördernd erwiesen etwa Einzelmerkmale der Umwandlungen (z.B. die Dorsolateral-Linien) zu verfolgen und darauf phylogenetische Zusammenhänge zu konstruiren. Dagegen wurden die Belemnitenrostren als ganze unter Betrachtung aller inneren und äusseren Merkmale und ihrer Veränderungen betrachtet und gewertet." The above authors have used a very demonstrative method of drawing phylogenetical trees, and introduced into paleozoology the concept of a 'phylogenetic field.' They understood each species or genus as some kind of field which has its limits in space and time, but which is invariably merging into other 'phylogenetical fields' of genera and species allied to it. These 'phylogenetical fields' may be drawn in the form of a diagram according to the stratigraphic range, breadth of variation and intergradations of the forms concerned, but the writers mostly preferred to construct them from photographed guards and from transparent sections arranged so as to represent objectively the limits of each field, breadth of variation and stratigraphic range, and above all their continuity. To illustrate the idea the writer reproduces herewith the diagram of the phylogenetic tree of the belemnites of the South German Lias and Dogger composed by Tripp (1940, p. 113).

Swinnerton (1939, 1940), Trueman (1924) and other British authors came to a very similar conclusion in their concept of 'plexus' and 'phylogenetic trends.'

The above discussed tendency to discard specimens as a foundation of paleozoological species and to use fossil populations (i.e. series of specimens assumingly respresenting these) contributes considerably to the phylogenetical method and makes it much more exact. It seems to be sufficiently evident that the old phylogenetical concept of 'phylogenetic lines' did not represent the true character of paleozoological evolution. The fact that in all numerous cases when paleozoological material is more or less plentiful and evolutionary

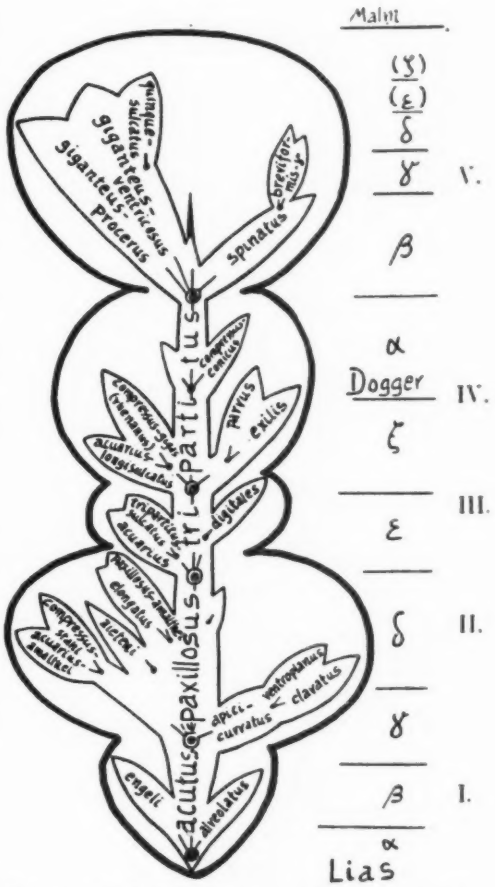

FIG. *1*—A phylogenetic tree of the belemnoids of the South German Lias and Dogger. The tree includes only belemnoid forms of the family Polyteuthidae Stolley, 1919. This name is taxonomically invalid (there is no genus *Polyteuthis*) and should be replaced by the name Belemnitidae d'Orbigny, 1842 s. str. (Tripp 1940, p. 113).

series continuous we observe not 'lines' but 'phylogenetical fields' or 'plexus' is very significant. It may be safely assumed that these concepts reflect much more correctly the character and course of evolutionary processes than the concept of 'phylogenetical lines.'

The writer himself has found the phylogenetical method and the above discussed concept of 'phylogenetical fields' or 'plexus' to be very useful in his studies of Upper Cretaceous belemnites. At the same time his study has shown that the correlative value of nearly all measurements of Upper Cretaceous belemnites is extremely low. Nearly all measurable characters of this group were proven to have about the same range of variation in different species and genera. Only two or three measurable characters from about a score of those investigated were proven to be of taxonomic value, and could be used for composition of statistical curves.

EVOLUTIONARY SERIES IN PALEONTOLOGY

It would seem to the writer that Clark (1945, p. 161), Newell (1948, p. 230, figs. 2a–b) and other investigators have somewhat overestimated the actual difficulties of finding many continuous evolutionary series in paleozoology. Their argument regarding the factors of breaks in sedimentation, geographical fragmentation of successive populations during the differentiation of a phyletic line, local extermination, fragmentary and scarcity of paleozoological material, etc., is of course quite correct when applied to pelecypods, gastropods, brachiopods, corals or any other group of fossils that are strongly dependent upon the character of the substratum during their life. Yet it does not apply to any great extent to some other groups of fossils which are essentially independent of the substratum and widely distributed horizontally. Planktonic, nekto-planktonic, or nektonic groups of fossils such as ammonoids, nautiloids, belemnoids, graptolites, etc. could scarcely be seriously affected by the above factors during their life. It is quite apparent that in such groups active interbreeding populations would mostly inhabit marine regions up to several thousands of miles in diameter, and in some cases might be practically worldwide, unless land barriers or climatic factors intervened (see pp. 32–33). As a result of their habitat, such forms were mainly entombed in true pelagic sediments, where continuous deposition is the rule. Accordingly it would not be expected that breaks in the sedimentation would preclude the restoration of a continuous, or in any case fairly complete evolutionary series, wherever the fossils themselves are sufficiently abundant for the purpose. These considerations are not theoretical, for paleozoological practice has already shown that pelagic facies may extend through a considerable stratigraphic interval, not being interfingered to any important degree with neritic or littoral facies, and showing throughout the whole successions sufficient abundance of the above groups of fossils.

The importance of the above discussed factors in paleozoological research that aims at the discovery of evolutionary series can scarcely be overestimated. Stolley (1897, pp. 218–220, 269; 1916, p. 98) Heinz (1928, p. 67) and other authors decades ago attempted to make use of a 'normal succession' for this kind of study (i.e. a sequence of beds representing the same or nearly the same pelagic facies without or nearly without breaks in the sedimentation and abundant in fossils). The study of Stolley (1897) of the 'normal succession' of white chalk and chalk marls at Luneburg has indeed revealed a fairly continuous evolutionary series of the genus *Gonioteuthis* Bayle, 1878 starting with *Actinocamax westphalicus* Schluter in the Coniacian and ending with the extinction of its youngest member *G. quadrata* (Blainv.) at the end of the Lower Campanian. Also the writer succeeded in establishing another fairly continuous evolutionary series of the genus *Belemnitella* d'Orbigny, 1842 em. Jeletzky, 1941 in the 'normal succession' of chalk marls in Southern Russia persisting from the Upper Coniacian till the end of the Upper Campanian (see fig. 2; Jeletzky 1948, pp. 593–94). Both evolutionary series embrace representatives of two genera, and persist through several stages of Upper Cretaceous. Another example of evolutionary series is presented in the work of Brinkmann (1929), although this succession does not meet the requirements of a 'normal succession.'

Brinkmann (1929, pp. 52–100) himself suggests considerable posthumus sorting and destruction of shells in many beds and used the term "plete" instead of "population" to avoid confusion. It is remarkable that even these unfavorable conditions did not prevent him from establishing a fairly continuous evolutionary record of *Kosmoceras*. Anyway it seems to be incorrect to quote this sample as evidence in favor of improbability of discovering evolutionary series of any considerable extent (e.g. Newell, 1948, p. 229). The results of Tripp, Zoch and Schwegler (see pp. 26–27) furnish other examples of continuous evolutionary series, despite the fact that these authors studied successions of beds much more closely resembling that of Brinkmann (1929) than 'normal successions.'

SEPARATIST TENDENCY

Still another troublesome problem in the description of new forms is that of the so called 'separatist tendency' of a great many paleozoologists throughout the world. Indeed some paleozoologists overlook many foreign species in the making of new ones, and are content if they compare their faunas with those of their own continent or country. Hence there arises a sort of 'national' paleozoology which grave influence on this science was ably expressed already by Pavlow (1892, pp. 61, 64) and recently again by Roger (1946, p. 272) in the following statement:

Le nombre de données nouvelles paraissent chaque année ne permet pas à un seul chercheur d'en avoir connaissance à l'échelle mondiale, ni même de lire tout ce qui peut parvenir à sa connaissance concernant un suget limité.

"Il an résulte qu'en général chacun à tendence à n'utiliser que la litérature assez facilement accessible et néglige nottamant les travaux paraissant en une langue étrangère qu'il connaît mal. Il est très caracteréstique de constanter que les publications allemandes ne contiennent que fort peu de références à articles français et réciproquement le plus souvent. Chaque pays est tenté de travailıer sa Paléontologie. Dans le domaine de la micropaléontologie, que les recherches pétrolifères ont singulièrement développé, les autors américains manifesten volontiers une tendence à decrire leurs faunas sans tenir grand compte des travaux antérieur européens. Les complications et les incertitudes des synonymies les ennuiant.

Ces remarques n'ont qu'une signification générale; d'heureuses exceptions existent. Cepandant, en dehors des difficultés matérielles de synonymie, accrues largement par le développement des recherches géologiques, aggravées par cette "orientation séparatiste," des inconvénients plus graves se font jour.

It can be easily seen that this 'separatist tendency' greatly adds to the multiplication of names and complexity of paleozoological nomenclature. It is partly due to the increasing output of paleozoological and stratigraphic literature, linguistic difficulties, and at present to the regrettable atmosphere of political tension throughout the world. The tendency is perhaps least prevalent in small countries of Western Europe, where it is, or should be, more or less apparent to everybody that most species and genera of a given zone or stage would necessarily be distributed beyond any political boundaries. On the contrary, vast countries and continents are more prone to 'national paleozoology,' for the very reason that it is so easy to assume that their faunas should differ quite naturally from those of any other part of the world.

This unfortunate situation may be corrected in several ways; by exchange of specimens or of plaster casts of types with museums in other continents; by travel and examination of specimens in the field and in museums of foreign countries; and by well illustrated works on the fossil faunas of all continents and countries. Although most modern works in paleozoology are well illustrated with good plates based on photographs, many of the older works are illustrated with fossil plates prepared from drawings; although most of these drawings are beautifully done and are even works of art, they do not always faithfully represent the details of ornament and other characters of the specimens figured. It is very desirable that many of these old works be revised, with new fossil plates, based on photographs not drawings.

HORIZONTAL RANGES OF FOSSIL SPECIES IN RELATION TO PHYLOGENY, PALEOCLIMATOLOGY AND PALEOGEOGRAPHY

There have been many attempts to prove theoretically narrow horizontal ranges of fossil species and presence of sharp distinctions between contemporary marine faunas of remote regions during the geological past. Several arguments were advanced in

favour of this hypothesis, besides the most popular Lyellian doctrine of uniformity. Some of these were reviewed by Stewart (1930, p. 108) in the following statement on Californian Aucellas:

> The relationships of the American forms with the European and Asiatic species is unknown to me and I have therefore preferred to use local names for the California species. In the elaborate work by Pavlow the California forms of *Buchia*, have been divided into at least sixteen species, most of which are also recognized in the Old World. Such a remarkable distribution and diversification must be verified by other workers before it can be accepted, . . . *Buchia* may have developed similar forms in the different regions but that would not justify the classification of these forms as species; it would be another example of parallel evolution. This parallel evolution may have been synchronous, but it cannot be assumed so until the time relations of the numerous forms have been established on the other grounds.

Doubts regarding broad horizontal ranges of fossil species are fairly common in world literature (e.g. Arkell, 1946, p. 23; Newell, 1949, pp. 221–222) on grounds similar to those quoted. It is assumed to be dangerous and even unwarranted to unite specifically, or even generically, morphologically similar fossils occurring in remote regions. Even complete morphological likeness of the forms concerned appear to some to be insufficient proof of specific identity because of assumed possibility of the development of morphologically similar forms in different regions. Such authors prefer to speak of "analogous species" rather than admit a broad horizontal distribution of a single species. The concept of parallel independent evolution used by these authors was recently justly and ably criticized by Van Hoepen (1946). It is likewise unacceptable to the writer, for it transgresses one of the main biological principles, expressed already by Darwin and recently ably reviewed by Simpson (1943, pp. 147, 156–159). According to this principle the degree of morphological likeness between fossil or recent forms or groups of forms correctly reflects their phylogenetical relationships and relative distance from a common ancestry. Accordingly all forms which are morphologically close enough to be considered as members of the same species or genus should be regarded as such disregarding other theoretical considerations. All cases of independent parallel development in different regions, homoeomorphy and convergence, so numerous in both paleo- and neozoology, do not contradict the above principle since such likenesses are always more or less superficial, and may be discovered by sufficient morphological investigation, even from fragmentary paleozoological material. The existence of phylogenetically independent, but morphologically quite similar forms of specific or any other rank is improbable from an evolutionary point of view. The common occurrence of parallel development, homoeomorphies, and convergences in different groups of fossils could indeed be discovered only by recognition of essential morphological distinctions in characters other than those leading to convergence.

In principle the possibility of the development of parallel and homoeomorphically similar branches of Aucellas in Eurasia and North America as suggested by Stewart (1930, p. 108) may be admitted. Nevertheless if such development actually took place substantial morphological differences according to the evolutionary concept should permit of its recognition. Otherwise similar forms, even from remote corners of the world, should in the writer's opinion be allocated to the same species. The risk of making mistakes in identification by such procedure is preferable to the complication of nomenclature and taxonomy by the use of different names for the same forms in different countries and continents (see also Pavlow, 1892, pp. 61, 64; Richardson, 1948 pp. 369–370).

The current view that a very broad intercontinental or even worldwide horizontal range of fossil species is improbable seems to be ill-founded in many instances. The opinion of d'Orbigny (1852), Pavlow (1892 etc.), Walther (1927) and many other prominent paleozoologists and biostratigraphers, that there is no legitimate reason to deny such ranges, at least for certain groups of marine invertebrates that were able to move across the oceans and to withstand or to adapt themselves to considerable changes in their environment, seems to be justifiable, all objections notwithstanding. The distance between any given regions at

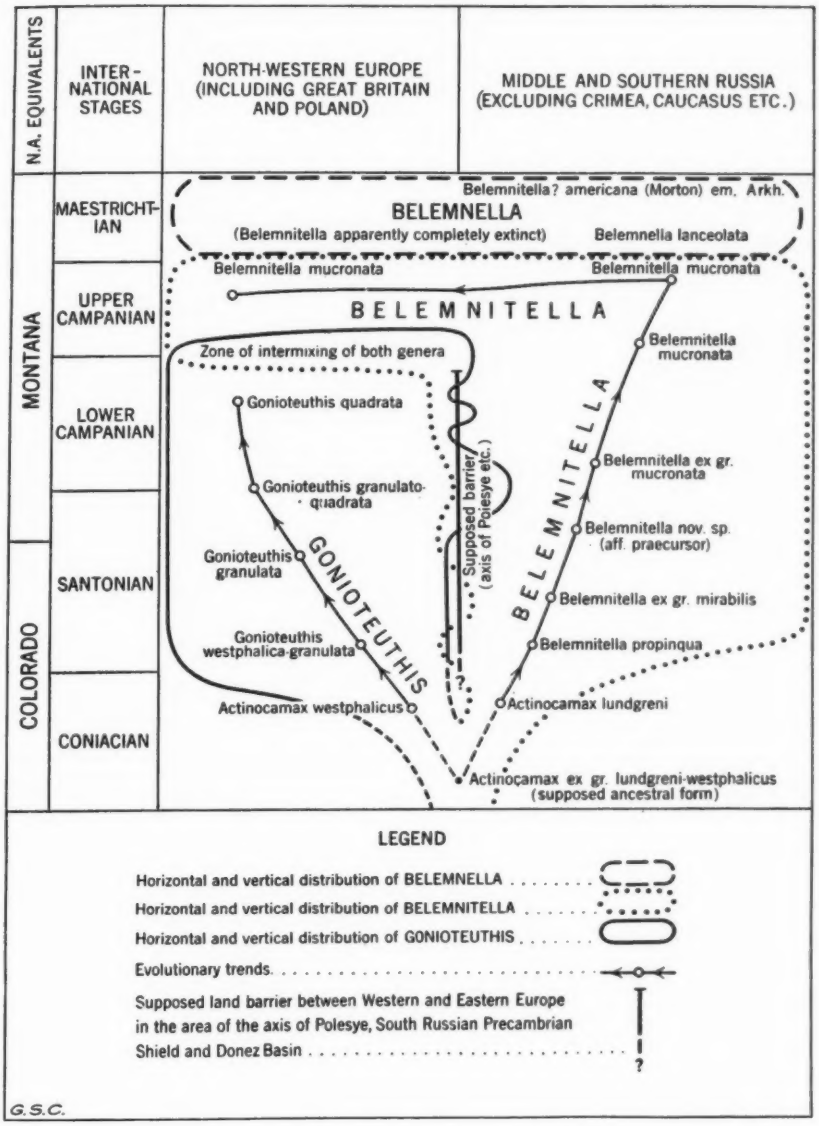

FIG. 2—Geographic distribution of the genera (phylogenetic branches) *Belemnitella* d'Orbigny 1842, *Gonioteuthis* Bayle 1878, and *Belemnella* Nowak 1913, in the boreal province of Eurasia. The crossing of the barrier by the lines of corresponding genera symbolizes their temporary and relatively rare penetration into the region of the other genus. The total extinction of *Belemnitella* at the lower boundary of the Maestrichtian is not yet proved beyond all doubt, although the evidence strongly favors it (Jeletzky, 1948b, pp. 591–592, 602). The taxonomic position of *Belemnitella* ? *americana* Morton and *B.* ? *americana* Arkhangelsky, and their specific identity remain somewhat uncertain (Jeletzky, 1948b, p. 597). The writer accepts their identity and tentatively refers them to the genus *Belemnella* pending the results of his revision of Eurasian and North American *Belemnitella*-like forms. The belemnoid fauna of the Maestrichtian both in Eurasia and North America is insufficiently understood and some revision of the above concept may be necessary. For further details see Jeletzky (1948b, 19—) and this paper.

any geologic time apparently has, in itself, comparatively little bearing on migration of faunas or differentiation of faunal assemblages in contemporary beds. As contended by Pfeifer (1927, pp. 6–8, 17–25 et. seq.), Clark (1945), pp. 160–161) and other authors, these processes were mainly controlled by factors such as climatic zones, land barriers, presence or absence of underwater ridges, oceanic currents, etc. These factors promoted or hindered exchange between faunas and brought about their distinctiveness or similarities with relatively little regard to the distance between the regions concerned.

It would also seem to the writer that much confusion is caused by dogmatic use of the Lyellian doctrine of uniformity. For it is obviously incorrect to apply the present marked climatic and topographic conditions, and the recent zoogeographic conditions caused by them, to past geologic periods older than Tertiary (e.g. Chamberlin, 1906, pp. 365, 372–373; Pfeifer, 1927, pp. 6–8 et. seq. Clark, 1945, 161–62 et seq.; Ramsay 1925). Existing climatic and topographic conditions are highly abnormal (postorogenetic), orocratic in the sense of Ramsay (1925, pp. 240 et seq.), and have nothing in common with those for example during the Mesozoic periods when continents apparently were very low and strongly peneplaned (pediocratic), the epicontinental transgressions much more widespread and the climatic belts consequently much less accentuated most of the time. Chamberlin (1906, pp. 372–373) proposed in this connection a challenging concept of the complete reversal of deep sea circulation with ultimate nivellation of the climates throughout the world. It is indeed tempting to combine hypotheses of Chamberlin (1906) and Ramsay (1925) and to consider the topographic differences between today and Mesozoic to be a probable cause of such reversal.

Some of these opinions are of course relatively well established and known. Yet the consequences are too often underrated by paleozoologists, who quite commonly simply draw conclusions about the zoogeographical conditions of the past from the contemporary zoogeographic evidence (e.g. Newell, 1949, pp. 221–222). In the opinion of the writer this is unwarranted, unless additional paleogeographical or paleoclimatological evidence suggests that the conditions of any particular geologic time were similar to the present conditions, which apparently was not often the case in Mesozoic or even Paleozoic time (see Ramsay, 1925, pp. 241 et seq.). The whole situation is further complicated by the possibility of continental drift, which, if present, might completely displace the equator and poles as compared with the present position of the continents.

It may be useful to quote a few examples, which will illustrate how negligible is the influence of distance in itself upon faunal differences between most of the contemporary formations as compared with the influence of other factors. Some of these were already reviewed by Smith (1904) etc. and other authors.

It is well known how distinct are the Upper Jurassic faunas of the neighbouring seas of Texas, Louisiana and other southern United States as compared with the similarity between contemporary faunas of Ellis or Fernie seas or these with faunas of Upper Jurassic seas of California, Oregon, Washington, British Columbia and Alaska. The faunas of these seas have practically nothing in common despite the circumstance that the distance between them is small, which is apparently due to the persistent presence of a narrow land barrier between them. On the contrary both Fernie (= Ellis) and Pacific Upper Jurassic seas are intimately related faunistically with the remote contemporary seas of Arctic and northern Eurasia (see pp. 34–35). These seas are also intimately related paleozoologically with one another, apparently due to the fact that their faunas migrated into them from one and the same Arctic basin situated farther to the north.

On the other hand the Upper Jurassic sea of Texas, Louisiana, Mississippi etc. was closely related faunistically with the Mediterranean and midcontinental Upper Jurassic seas of Western Europe, apparently due to the free connection with them. And it should be borne in mind that the real amount of faunistic affinities of all these North American seas with corresponding seas of Eurasia may be considerably obscured due to isolationist tendencies in modern paleozoology (see p. 29).

It would be not an overstatement to say

that these North American seas, even in the present unsatisfactory state of our knowledge of their faunal relations, may be more easily correlated with corresponding remote Eurasian seas than with one another. The same is probably true for the Lower Cretaceous seas of North America but our present knowledge of these strata and their faunas is too unsufficient to allow any definite conclusions. It is only certain that the Neocomian faunas of the Pacific coast are as closely related to the contemporary boreal faunas of the Arctic and northern Eurasia as are the Upper Jurassic faunas. Here too the real amount of faunistic affinities is probably much greater than it now appears to be.

Likewise in Upper Cretaceous time faunistic differences between contemporary faunas of the seas of the Pacific coast and Western Interior of North America are extremely great and striking despite the negligible distance between these seas. At the same time the so called Nanaimo (or Chico) fauna may be easily recognized along the whole Pacific coast of North America and beyond, even as far as the Indo-Pacific region or Antarctic, where many of its species were discovered by Kilian and Reboul (1908) and other authors.

The best way to correlate the deposits of the Chico group and its equivalents (Nanaimo series etc.) with those of the Colorado-Montana groups may well be that of comparing them independently with the remote Eurasian or Indo-African faunas of the same age.

One of the most striking examples of nearly worldwide distribution of the same faunas is presented by the Upper Cretaceous faunas of Madagascar, which are so intimately related to the contemporary faunas of the Mediterranean province of Eurasia and to the Indo-Pacific province that at some horizons the investigators have found more than 75% of the cephalopod species to be specifically identical either with West European or with Indo-Pacific faunas (see Basse, 1931, Collignon, 1931, 1938 etc.). The same is true of *Inoceramus* which accordingly to Heinz (1928, 1932 etc.) and other authors shows a practically worldwide distribution of many of its species. Another illustrative example as to the prevailing influence of other factors than mere distance may be taken from Upper Cretaceous belemnites of Eurasia. Jeletzky (1948b, pp. 592–93) has shown that the belemnoid faunas of northeastern and northwestern Europe were quite distinct during the whole of Santonian and Lower Campanian time, a particular group inhabiting each region (*Gonioteuthis* Bayle, and *Belemnitella* d'Orbigny emend Jeletzky). Each of these groups evolved during this period of time quite independently along parallel lines, and they both apparently originated in the same ancestral stock (*Actinocamax* Miller, 1826) in the Coniacian. Jeletzky (1948, pp. 593–94) ascribed the taxonomic independence of these evolutionary series to the isolation of the middle Russian boreal sea from that of northwestern Europe and Poland by a barrier in the region of the axis of Polesye. The presence of excellent, practically continuous, evolutionary series of each branch (genus) supplies an ample proof of their independent evolution; they scarcely mingled with one another except near the boundary between the regions, until the late Lower Campanian when the *Belemnitella* branch expanded throughout the whole of the boreal province of Eurasia and *Gonioteuthis* vanished at about the same time (see fig. 2). It is sufficiently apparent that this increase in the range of *Belemnitella* of some 1500 miles or more, which occurred in a negligible interval of time geologically speaking, was due to the submergence of the Polesye axis and that distance in itself did not play any perceptible role in restricting the previous range of this branch or in its later rapid expansion. The same seems to be true for the distribution of Jurassic ammonoid faunas of Eurasia which were nearly uniform from England to Russia until late Upper Jurassic, when a regression of the sea partly isolated several Eurasian basins from one another, at once causing pronounced faunistic differences. Accordingly the writer cannot accept the view of Arkell (1946, pp. 23 et. seq.), who considers the influence of distance on the differentiation of faunas to be of equal importance with that of geographical or climatic isolation.

It seems to the writer that the paleofaunistical and paleogeographical examples cited are sufficient to show that the current views as to the prevailing distinctness of North American Upper Jurassic and Cretaceous faunas from these of Eurasia and other parts

of the world lack a proved foundation and are in need of thorough revision. Contemporary views on this subject seem partly to arise from theoretical prejudice.

It seems to the writer that the views of the old paleozoological school favoring the worldwide extent of statigraphical stages and even zones and very broad, even worldwide horizontal range of certain groups of fossils species are still valid and preferable to the current prevailing opinion discussed above. Also it is apparently possible to maintain the view that even the shortest subdivisions of geologic time now in use are still prolonged enough to allow many groups of marine invertebrate fossils to migrate practically around the whole globe without pronounced geographic breaks in active interbreeding populations when migrations are not precluded by other factors than mere distance (e.g. land barriers, climatic zones, etc.). Most of the evidence available indicates that present-day pronounced climatic zones and narrow horizontal ranges of species and even genera are exceptional and cannot be applied to the marine fossils of the past in many instances.

CORRELATION OF SOME UPPER JURASSIC AND CRETACEOUS FAUNAS ON BOTH SIDES OF THE ATLANTIC

The inference of modern paleozoological nomenclature and taxonomy exerted on the study of various intercontinental geological-stratigraphical problems may be illustrated by many concrete examples. The problem as a whole is far too extensive to be discussed here, and the writer cites only a few illustrative examples taken from the Upper Jurassic and Cretaceous faunas of this continent and Eurasia.

Attempts so far to correlate Uppermost Jurassic and Cretaceous formations on both sides of the Atlantic have not been quite satisfactory. Correlations of Upper Cretaceous series are, for example, vague and very tentative. North American authors, who recently have attempted such correlation (e.g. Stephenson, Whyte and Gardner in the work of Balk and Ruedemann, 1939, pp. 546–47; Stephenson & Reeside, 1938, pp. 1637–38; Stephenson 1941, pp. 34–35) ascribed failure to arrive at more satisfactory results to the fact that there are only very few common or closely related species of index fossils in synchronous deposits on both sides of the Atlantic. The same can generally be said of Eurasian authors. Lists of fossils presented in the literature on Upper Cretaceous of both continents, indeed, scarcely show more than three to five percent of species common to both sides of the Atlantic. For some groups the percentage is probably even less than this. The same is true for Lower Cretaceous and Upper Jurassic deposits.

It is important to decide whether the Upper Jurassic and Cretaceous faunas of this continent are really so distinct from these of Eurasia as these lists indicate, or whether there has been much over-speciation and consequent unnecessary complication in terminology.

Since objections to the possible affinity between contemporary marine faunas of remote regions in the past are, as already stated, considered by the writer to have little support it is interesting to inquire further into Mesozoic faunal distribution. An analysis of certain Upper Jurassic and Cretaceous faunas on both sides of the Atlantic indicates at once that there is no lack of considerable affinity. Although the prevailing number of groups of index fossils (e.g. ammonites, belemnites, inocerami and some other pelecypods) in fossil lists show an extreme rarity of species held in common or none at all (most groups of pelecypods), a few other groups (e.g. Aucellas or Upper Cretaceous belemnoids) are assumed to show considerable affinity, by nearly all students of both continents and many common species are cited. It is remarkable that these instances of affinity should be noted when the North American and Eurasian material was studied together by the same students (e.g., Lasswitz, 1904; Roemer, 1852; Pavlow, 1892, 1907), or when the literature of both continents was extensively consulted by them (Grossouvre, 1893; Smith, 1904, etc.; Arkhangelsky, 1912; Anderson, 1938, 1945, etc.). Still more remarkable is the circumstance that in such cases the degree of Eurasian affinities of different groups occurring in the same localities and in the same horizons and studied by the same authors are highly unequal. For example, Anderson (1938, 1945) gives about

75% of *Aucella* species as common to North America and boreal provinces of Eurasia and the Arctic. At the same time he scarcely mentions any common species of Ammonoidea and Belemnoidea. And yet the conclusions of Anderson (1938, 1945) as to the *Aucella* are in agreement with the conclusions of all Russian (e.g. Pavlow, 1907) and nearly all North American authors and with the personal experience of the writer as well. The revision of Canadian Aucellas by him which is now in progress shows that the views of Anderson and other North American and Russian authors are quite correct, while the contrary views of Stewart (1930) and Crickmay (1930) are not. In this connection it may be useful to mention that the writer cannot recognize specific independence of some of Lower Cretaceous Aucellas described by Crickmay (1930). So he considers *Aucella cascadensis* Crickmay, 1930 to be synonymous with *Aucella okensis* Pavlow, 1907 and *Aucella spasskenscoides* Crickmay 1930 with *Aucella volgensis* Lahusen, 1888. Some other species described by Crickmay (1930) may be synonyms of already described species. Also the belemnoid species of Crickmay (1930) and Anderson (1938, 1945) seem to be mostly synonymous with already described Eurasian species (see also Pavlow, 1892, pp. 62–64).

Although not qualified as yet to form a definite judgment on the affinities and differences of the ammonoid faunas of the above authors, the writer would like, nevertheless, to stress the fact that it would be most unusual if these nektonic or nektoplanktonic forms were completely distinct from the contemporary ammonoid faunas of the boreal province of Eurasia, when such benthonic forms as *Aucella* from the same localities and horizons are undoubtedly very closely related to these and there are good reasons to assume the close affinity of the belemnoid faunas.

The recent revision of Canadian Turonian or Coniacian *Actinocamax* species by the writer (in press) has also asserted that nearly all Canadian forms known so far are intimately allied, and in some cases probably specifically identical with contemporary Eurasian forms. The investigation of Campanian and Maestrichtian *Belemnitella*-like forms of the United States by the writer, as yet unfinished, leads to the same conclusion. The writer has no doubt that a thorough restudy of North American and Eurasian ammonites and inocerami will yield the same results. Already it has been suggested that many well known index species of ammonites, inocerami and belemnites described under different names on both sides of the Atlantic are as a matter of fact specifically identical, or at any rate should be treated as subspeces of the same species (e.g., Anderson, 1938, 1945; Arkhangelsky, 1912, 1916; Elias, 1933; Frech, 1915; Grossouvre, 1893; Heinz, 1928, etc., Lasswitz, 1904, Nowak, 1916; Pavlow, 1892; Ravn, 1918; Roemer, 1852) yet this has received little attention, and as yet no thorough comparison of corresponding groups on both sides of the Atlantic for the purpose of discovering the real extent of their specific similarity has so far been made. The writer has no doubts that attempts that have already been made in this direction, although undoubtedly inaccurate in many details, are first steps in a right direction.

It should in particular be borne in mind that the data about the affinities of North American and Eurasian Upper Jurassic and Cretaceous faunas are very scanty and incomplete. Many other cases of affinity of faunas are undoubtedly disguised under different names, and cannot be recognized without extensive research. In many instances no effort has been made to prove or to disprove that described species on different sides of the Atlantic are actually distinct. The problem of taxonomic relations of North American and Eurasian species of supposedly contemporary beds is commonly simply ignored by investigators. There are of course happy exceptions both in North American and Eurasian literature.

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NORTH AMERICAN JURASSIC FORAMINIFERA: I. THE TYPE REDWATER SHALE (OXFORDIAN) OF SOUTH DAKOTA

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ABSTRACT—Fifty-six species of Foraminifera, belonging to eight families, are described and figured from the type Redwater shale member of the Sundance formation of South Dakota. Over two-thirds of the species belong to the Lagenidae.

INTRODUCTION

DURING September 1948, extensive collections were made by Ralph W. Imlay and Alfred R. Loeblich, Jr., from the Sawtooth, Piper, Rierdon, and Swift formations of Montana, from the Sundance formation of Wyoming, and from the Gypsum Spring formation and Stockade Beaver shale, Hulett sandstone, and Redwater shale members of the Sundance formation in the Black Hills area of South Dakota and Wyoming. It is the writers' intention to describe the Jurassic foraminiferal faunas from each of these units in the near future, the present paper being the first of the series.

Samples were collected from the most complete and best-exposed sections, from all lithologic variations represented and from areas as widely distributed geographically as possible. Particular regard was given to the Jurassic faunal zones recently established by Imlay (1948) in the three states mentioned above. Examination of these samples has shown well-developed and distinctive faunules in nearly all the formations.

EARLIER JURASSIC FORAMINIFERAL STUDIES

Little has been published on North American Jurassic Foraminifera. Morey (1931, p. 327) first recorded Foraminifera from Jurassic strata in North America. Six genera, *Robulus*, *Globigerina*, *Frondicularia*, *Nodosaria*, *Clavulina*, and one undetermined genus were recorded from the Sundance formation of Wyoming. In addition, Morey noted the presence of Foraminifera throughout the lower 200 feet of the formation.

Sandidge (1933a, p. 204) recorded a fauna from Montana that consists of about a dozen species of Foraminifera belonging to the family Lagenidae, which he considered identical with species described by Terquem from the lower Oolite or Bajocian of France. Later (1933b, p. 174) Sandidge described a section from Montana in which a lagenid foraminiferal fauna was recovered from three horizons in the Sundance formation. Twelve species of Foraminifera were figured, described and referred to species described by Terquem or by Terquem and Berthelin. Sandidge compared the fauna to that of the French Bajocian described by Terquem, which Sandidge considered to be of Lower Jurassic age. However, he also commented that the Sundance in its general composition had an Upper Jurassic affinity.

Wickenden (1933, p. 157) described a dominantly lagenid foraminiferal fauna from three wells in Saskatchewan and Alberta and stated that the fauna was similar to that described by Sandidge and of about the same age. According to Wickenden the species compared favorably with those described from the Dogger of Central Europe and the Bajocian of France. The possibility of zoning the Jurassic on the basis of the microfauna was suggested, as Wickenden found the same succession of species and fauna in the three wells studied.

STRATIGRAPHY

The Redwater shale was defined by Imlay (1947, p. 259) as the uppermost member of the Sundance formation in the Black

[1] Arrangement of names alphabetical, no seniority implied.
[2] Mrs. Alfred R. Loeblich, Jr.

Hills area of South Dakota and eastern Wyoming. The thickness varies from 80 to 190 feet or more, and the Redwater consists of greenish-gray to gray, soft fissile shale, including some soft glauconitic sandstone in the lower 20 to 30 feet, and thin beds of coquinoid or oolitic limestone in the upper half.

Locality.—Type section of the Redwater shale member of the Sundance formation, one-half mile north of Redwater Creek opposite the mouth of Crow Creek, about 7 miles northwest of Spearfish, in the S. ½, sec. 2, T. 7 N., R. 1 E., Butte County, S. Dak. Measured by R. W. Imlay and William Saalfrank in June 1945. Microfossil samples collected September 21, 1948, by R. W. Imlay and A. R. Loeblich, Jr.

	Feet
Morrison formation, basal part	
5 to 10 feet of soft yellow sandstone, overlain by dark gray shale containing small calcareous pellets.	
Sundance formation	
Redwater shale member:	
Shale, in part silty near base, soft, dark gray; contains many pieces of selenite and abundant belemnites; lenses of sandy limestone present at several levels, many fossiliferous limestone concretions in upper half. U.S.G.S. Mesozoic collection 19570, made 55 feet above the base in lens of sandy limestone, contains *Cardioceras* (*Scarburgiceras*) *cordiforme* (Meek and Hayden), *C.* (*S*) *wyomingense* Reeside, *Grossouvria* (*Poculisphinctes*) cf. *G. trinys* (Buckman) and other fossils. Twelve microfossil samples were collected from this unit as follows: J-50a, 5 to 15 feet above base of unit; J-50b, 15 to 22 feet; J-50c, 22 to 33 feet; J-50d, 33 to 41 feet; J-50e, 41 to 48 feet; J-50f, 48 to 55 feet; J-50g, 55 to 62 feet; J-50h, 62 to 68 feet; J-50i, 68 to 75 feet; J-50j, 75 to 82 feet; J-50k, 82 to 87 feet; J-50l, 87 to 108 feet above base of unit	118
Sandstone, soft, medium yellow, shaly to thick-bedded	6
Shale and sandy shale, soft, gray. Sample J-49 (barren of Foraminifera)	10
Sandstone, soft, yellow	1
Shale, soft, gray. Sample J-48 (barren of Foraminifera)	1
	136
Lak member:	
Shale, light red, weathers pinkish; contains 2 feet of soft white sandstone about 24 feet above base	50

The Redwater shale member includes in its lower portion the *Cardioceras cordiforme* zone, stratigraphically the highest ammonite zone recognized in the Western Interior Jurassic. Imlay (1947, p. 261) has indicated that the zone represents most of the *mariae* zone of northwest Europe. On the basis of the widespread occurrence of *Cardioceras* and associated mollusks, Imlay has correlated the Redwater with the Stump sandstone of eastern Idaho and western Wyoming, the Curtis formation of Utah, the Swift formation of Montana, and the "Upper Sundance" of central Wyoming.

METHODS OF STUDY

All samples collected are channel samples which were prepared in the laboratory by boiling in soda ash solution and then washed by decantation. Samples were then sieved through cloth screens into seven fractions (approximate mesh sizes 10, 20, 40, 60, 80, 100, and pan) to facilitate picking. In general, within the type area of the Redwater shale, the very coarse fractions (10 and 20) are barren of Foraminifera, and specimens are rare in the finer fractions (100 and pan) as well. All samples were washed, picked, and sorted by A. R. Loeblich, Jr. Illustrations are camera lucida drawings by Helen Tappan Loeblich.

ACKNOWLEDGMENTS

The writers are indebted to Dr. J. B. Reeside, Jr., for his interest in this study and for making arrangements for joint field work with Dr. R. W. Imlay. To Dr. Imlay we are indebted for his guidance in the field and his assistance in the collection of samples. Imlay's wide knowledge of the interior Jurassic made it possible to collect in a relatively short period of time most of the important sections in Montana, northern Wyoming, and western South Dakota. We are indebted to the United States Geological Survey for defraying all field expenses.

COMPOSITION OF THE FAUNA

Fifty-six species of Foraminifera were found in the type locality of the Redwater. They represent eight families and 29 genera. The majority of the forms belong to the Lagenidae, 40 species representing 16 genera of this family. The Polymorphinidae and

Lituolidae are each represented by five species, the Spirillinidae by two, and the Reophacidae, Verneuilinidae, Miliolidae and Trochamminidae each by a single species. Although seven-eighths of the species belong to calcareous genera, the few species of arenaceous Foraminifera comprise a fairly large percentage of the total fauna, as specimens of these are quite abundant.

SYSTEMATIC DESCRIPTIONS

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

REOPHAX SUNDANCENSIS Loeblich and Tappan, n. sp.

Plate 11, figure 1

Test free, small, elongate, tapering very slightly, consisting of four to six slightly inflated chambers in a linear series; sutures distinct, depressed, straight; wall coarsely arenaceous, surface rough; aperture simple, terminal, at the end of a short neck.

Length of holotype 0.7 mm., greatest diameter 0.23 mm.; other specimens vary in length from 0.42 mm. to 0.7 mm., average 0.52 mm. in length.

Types and occurrence.—Holotype (USNM 104915) from Sample J-50 c; unfigured paratypes (USNM 104916) from Sample J-50 d.

Remarks.—*Reophax sundancensis*, n. sp., differs from *R. suevica* Franke in having lower, less bulbous chambers and in having a rougher surface. It differs from *R. scorpiurus liasica* Franke in the coarser finish and less tapering test.

Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES TRYSSA Loeblich and Tappan, n. sp.

Plate 11, figures 2 a–b

Test free, small, planispirally coiled, periphery rounded; chambers increasing rather rapidly in size as added, about five in the last whorl; sutures distinct, depressed, straight; wall finely arenaceous, surface smoothly finished; aperture a low arch at the base of the final chamber.

Greatest diameter of holotype 0.36 mm., least diameter 0.29 mm., greatest thickness 0.13 mm.; other specimens vary in diameter from 0.26 mm. to 0.39 mm.

Types and occurrence.—Holotype (USNM 104917) and unfigured paratype (USNM 104919) from Sample J-50 f.

Remarks.—*Haplophragmoides tryssa*, n. sp., differs from *Haplophragmium crassum* Reuss in being much smaller and in having less inflated chambers. It is similar in size and chamber arrangement to *H. kirki* Wickenden, but differs in having less inflated chambers.

Genus AMMOMARGINULINA Wiesner, 1931

AMMOMARGINULINA BARYNTICA Loeblich and Tappan, n. sp.

Plate 11, figures 3–6

Test free, large, flattened, early portion close-coiled, later chambers uniserially arranged, periphery rounded; from five to eight chambers in the last whorl of the involute coil, followed by as many as four broad, low uniserial chambers; sutures slightly depressed, especially at the margins of the test, so that a somewhat lobulate periphery results, sutures straight to slightly curved backwards at the periphery in the coil, nearly straight in the uniserial portion; wall coarsely arenaceous, with considerable cement, so that the surface is rather smoothly finished; aperture terminal, simple.

Greatest length of holotype 1.43 mm., greatest breadth of coiled portion 0.96 mm., greatest breadth of uniserial portion 0.94 mm., greatest thickness 0.31 mm. Other specimens range from 0.68 to 2.70 mm. in length.

Types and occurrence.—Holotype (USNM 104920) from Sample J-50 b; paratypes (USNM 104921 a–b) from Sample J-50 c, (USNM 104922) from Sample J-50 d, and (USNM 104923) from Sample J-50 e.

Remarks.—*Ammomarginulina baryntica* n. sp., differs from *Ammobaculites cuyleri* Tappan in attaining nearly twice its size in adult specimens, and in having lower uniserial chambers and a less compressed test.

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES COBBANI Loeblich and Tappan, n. sp.

Plate 11, figures 9a–13

Test free, of medium size, flattened, early portion close-coiled, centrally umbilicate, later portion uniserial, periphery rounded; about six to seven chambers in the plani-

spiral coil, which may be slightly off-center in some specimens and appear almost trochoid, coil followed by as many as four broad, low uniserial chambers, which increase very slowly in height until the final chamber, which is about twice the height of the earlier chambers; sutures distinct, thickened, nearly straight, somewhat depressed, giving a lobulate appearance to the periphery; wall arenaceous, with considerable cement, surface smoothly finished; aperture terminal, elongate.

Length of holotype 0.75 mm., greatest breadth of coil 0.39 mm., greatest breadth of uniserial portion 0.31 mm., greatest thickness 0.21 mm. Other specimens are from 0.31 mm. to 0.88 mm. in length.

Types and occurrence.—Holotype (USNM 104924) and figured paratypes (USNM 104925 a–d) from Sample J-50 c; unfigured paratypes (USNM 104926) from Sample J-50 d.

Remarks.—*Ammobaculites cobbani*, n. sp., is similar to *A. subcretaceus* Cushman and Alexander, but may be distinguished by the more regular uniserial portion, slightly larger size and more elongate aperture. It is distinguished from *A. tyrrelli* Nauss in being more compressed in the uniserial portion, and in having lower chambers.

AMMOBACULITES IMLAYI Loeblich and Tappan, n. sp.
Plate 11, figures 17 a–b

Test free, small, early portion planispiral and compressed, later uniserial portion rounded in section; chambers numerous, four to five in the tiny flattened coil, followed by four to five uniserial chambers, which have a diameter about equal to that of the entire coil; sutures distinct, straight, slightly depressed; wall arenaceous, of medium-sized grains, surface roughened; aperture simple, terminal.

Greatest length of holotype 0.49 mm., greatest diameter of coil 0.13 mm., greatest breadth of uniserial portion 0.16 mm., greatest thickness 0.16 mm. Other specimens vary in length from 0.29 mm. to 0.55 mm.

Types and occurrence.—Holotype (USNM 104930) from Sample J-50 d; unfigured paratypes (USNM 104931) from Sample J-50 c.

Remarks.—*Ammobaculites imlayi*, n. sp., differs from *A. reophaciformis* Cushman in possessing a more conspicuous coil and in having a much smaller and less tapering test. It differs from *A. formosensis* Nakamura in being one-half as large, with specimens of the same number of chambers.

AMMOBACULITES VENUSTUS Loeblich and Tappan, n. sp.
Plate 11, figures 7–8b

Test free, small, flattened, early portion planispiral and evolute, later portion uniserial, periphery rounded; chambers increasing rapidly in size in the coiled portion, about five to six in the last whorl, then increasing more slowly in size in the uniserial portion, with about three uniserial chambers present; sutures distinct, slightly depressed, nearly straight in the coiled portion, somewhat oblique in the uniserial portion, highest on the dorsal margin; wall finely arenaceous, with considerable cement, surface smoothly finished; aperture terminal, simple.

Greatest length of holotype 0.49 mm., greatest breadth of coil 0.23 mm., greatest breadth of uniserial portion 0.18 mm., greatest thickness 0.10 mm. Other specimens are from 0.34 mm. to 0.52 mm. in length.

Types and occurrence.—Holotype (USNM 104927) and figured paratype (USNM 104928) from Sample J-50 c; unfigured paratypes (USNM 104929) from Sample J-50 g.

Remarks.—*Ammobaculites venustus*, n. sp., is distinguished from *A. compressa* Cushman and Waters in having a less compressed test, in being somewhat smaller in size, and in possessing oblique sutures in the uniserial portion. It differs from *A. subcretaceus* Cushman and Alexander in the smaller size, more regular and oblique sutures in the uniserial portion and more smoothly finished surface.

Family VERNEUILINIDAE
Genus VERNEUILINOIDES Loeblich and Tappan, 1949
VERNEUILINOIDES TRYPHERA Loeblich and Tappan, n. sp.
Plate 11, figures 16 a–b

Test free, minute, tapering, triserial, subtriangular in section, periphery rounded;

chambers subglobular, increasing rapidly in size as added; sutures distinct, depressed; wall finely arenaceous, with considerable cement, surface smooth; aperture a high arch at the base of the last-formed chamber.

Length of holotype 0.16 mm., greatest breadth 0.10 mm. Other specimens are from 0.16 mm. to 0.34 mm. in length.

Types and occurrence.—Holotype (USNM 104932) from the type Redwater shale member of the Sundance formation, Sample J-50 g; unfigured paratypes from the "Upper Sundance" (86 to 92 feet above the base), along the east side of Red Gulch about 2½ miles south of the Little Big Horn River in sec. 22, T. 58 N., R. 89 W., Sheridan County, Wyo.

This species is rare in the type locality of the Redwater, but more frequent in the "Upper Sundance" of Wyoming, from which paratypes are listed.

Remarks.—*Verneuilinoides tryphera* differs from *Verneuilina anglica* Cushman in being less than one-fourth as large and in possessing fewer chambers. It differs from "*Verneuilina*" *cummingensis* Nauss in having a more flaring test and in being less than one-half as large. In size it is similar to *Verneuilina perplexa* Loeblich, but it is more regular in chamber arrangement and lacks the terminal aperture which was developed in *V. perplexa*.

Family MILIOLIDAE
Genus MASSILINA Schlumberger, 1893
MASSILINA sp.
Plate 11, figures 15 a–b

Test free, small, narrow and elongate, early portion quinqueloculine, later chambers added alternately on opposite sides of the test, periphery rounded; four elongate chambers visible on each side of the test; sutures distinct, depressed; wall probably calcareous and imperforate, but specimens available are all represented only by internal casts; aperture at the end of the final chamber.

Length of figured specimen 0.29 mm., greatest breadth 0.10 mm., greatest thickness 0.07 mm.

Types and occurrence.—Figured specimen (USNM 104934) from Sample J-50 a.

Remarks.—This species is represented by rare specimens, which are invariably preserved only as limonitic casts, hence no specific determination has been attempted.

Family TROCHAMMINIDAE
Genus TROCHAMMINA Parker and Jones, 1859
TROCHAMMINA LATHETICA Loeblich and Tappan, n. sp.
Plate 11, figures 14 a–c

Test free, small, trochoid, flattened, ventrally umbilicate, periphery subacute; about two whorls visible dorsally, only the six chambers of the last whorl visible ventrally; sutures obscure in the early portion, slightly depressed in the last whorl, giving a slightly lobulate appearance to the periphery; wall finely arenaceous, with considerable cement, surface smoothly finished; aperture at the inner margin of the ventral side of the chamber.

Greatest diameter of holotype 0.26 mm., least diameter 0.21 mm., greatest thickness 0.08 mm. Other specimens are from 0.13 to 0.26 mm. in greatest diameter.

Types and occurrence.—Holotype (USNM 104935) from Sample J-50 k.

Remarks.—*Trochammina lathetica* may be distinguished from *T. albertensis* Wickenden by the less conical form in peripheral view, and from *T. wickendeni* Loeblich by its smaller size, more obscure early sutures and more lobate outline.

Family LAGENIDAE
Genus LENTICULINA Lamarck, 1804
LENTICULINA AUDAX Loeblich and Tappan, n. sp.
Plate 11, figures 18a–21b

Test free, large, lenticular, planispiral and involute, periphery subacute, with a somewhat thickened keel; chambers numerous, increasing gradually in size as added, about nine in the last whorl of juvenile specimens, with as many as 14 in the last whorl of well-developed specimens; sutures distinct, slightly thickened, gently curved backwards at the periphery; wall calcareous, finely perforate, surface smooth, with no ornamentation other than the peripheral keel; aperture at the dorsal angle of the final chamber, radiate.

Greatest diameter of holotype 1.51 mm., least diameter 1.30 mm., greatest thickness

0.52 mm. Other specimens are from 0.29 to 1.51 mm. in greatest diameter.

Types and occurrence.—Holotype (USNM 104936) and unfigured paratypes (USNM 104940) from Sample J-50 b; figured paratype (USNM 104937) and unfigured paratypes (USNM 104939) from Sample J-50 c; figured paratypes (USNM 104938 a–b) from Sample J-50 g.

Remarks.—*Lenticulina audax*, n. sp., may be distinguished from *Cristellaria diademata* Berthelin by being approximately one-third larger and having twice the number of chambers in the final whorl. *Cristellaria gaultina* Berthelin agrees in size with the present species, and has approximately the same number of chambers in the final whorl, but is relatively much thicker through the umbo. *Cristellaria helios* Terquem is approximately one-half the size of *Lenticulina audax* and possesses limbate sutures, while *Cristellaria mamillaris* Terquem differs in being nearly twice as large and in possessing fewer chambers in the final volution.

Genus ASTACOLUS Montfort, 1808

ASTACOLUS AGALMATUS Loeblich and Tappan, n. sp.

Plate 12, figures 5 a–7

Test free, large, compressed, auriculate in outline, early portion coiled, later uncoiling, periphery subacute, with a narrow dorsal keel; chambers numerous, low and elongate, as many as 16 in well-developed specimens, later uncoiled chambers reaching back to the coil; sutures distinct, thickened, slightly raised, gently curved; wall calcareous, finely perforate, surface smooth; aperture radiate, at the dorsal angle.

Length of holotype 1.64 mm., greatest breadth 0.94 mm., greatest thickness 0.23 mm. Other specimens are from 0.73 mm. to 1.64 mm. in length.

Types and occurrence.—Holotype (USNM

EXPLANATION OF PLATE 11

FIG. *1*—*Reophax sundancensis* Loeblich and Tappan, n. sp. Side view of holotype (USNM 104915), ×64. (p. 41)

2a–b—*Haplophragmoides tryssa* Loeblich and Tappan, n. sp. *2a*, side view of holotype (USNM 104917); *2b*, edge view; ×64. (p. 41)

3–6—*Ammomarginulina baryntica* Loeblich and Tappan, n. sp. *3*, side view of paratype (USNM 104922) showing well-developed uniserial portion; *4a*, side view of holotype (USNM 104920); *4b*, edge view; *5*, paratype (USNM 104921a) with only the early coiled portion; *6*, paratype (USNM 104921b) showing specimen with small coiled portion and well-developed uniserial portion; all ×22. (p. 41)

7–8b—*Ammobaculites venustus* Loeblich and Tappan, n. sp. *7*, side view of small paratype (USNM 104928); *8a*, side view of holotype (USNM 104927) showing well-developed coil; *8b*, edge view; all ×48. (p. 42)

9a–13—*Ammobaculites cobbani* Loeblich and Tappan, n. sp. *9a*, side view of holotype (USNM 104924) showing well-developed coil; *9b*, edge view, showing trochoid tendency of coiled portion; *9c*, top view, showing slitlike aperture; *10*, side view of paratype (USNM 104925a) showing well-developed uniserial portion; *11*, side view of small paratype (USNM 104925b), showing only the coil; *12*, side view of paratype (USNM 104925c) showing beginning of uniserial development; *13*, side view of small paratype (USNM 104925d) showing range in size of this species; all ×48. (p. 41)

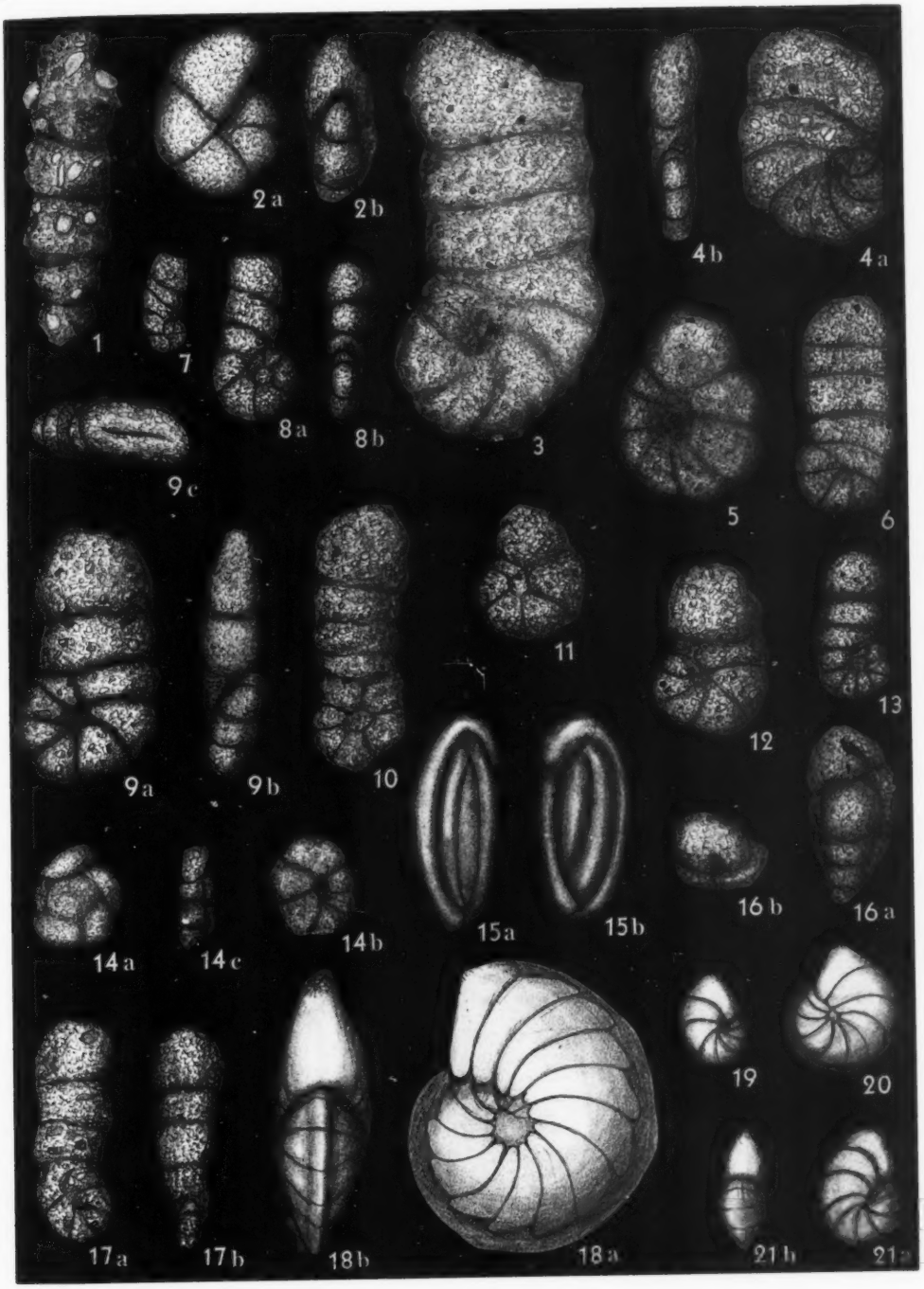
14a–c—*Trochammina lathetica* Loeblich and Tappan, n. sp. *14a*, dorsal view of holotype (USNM 104935), showing obscure central portion of coil; *14b*, ventral view; *14c*, edge view; ×64. (p. 43)

15a–b—*Massilina* sp. Opposite views of pyritized specimen (USNM 104934); ×106. (p. 43)

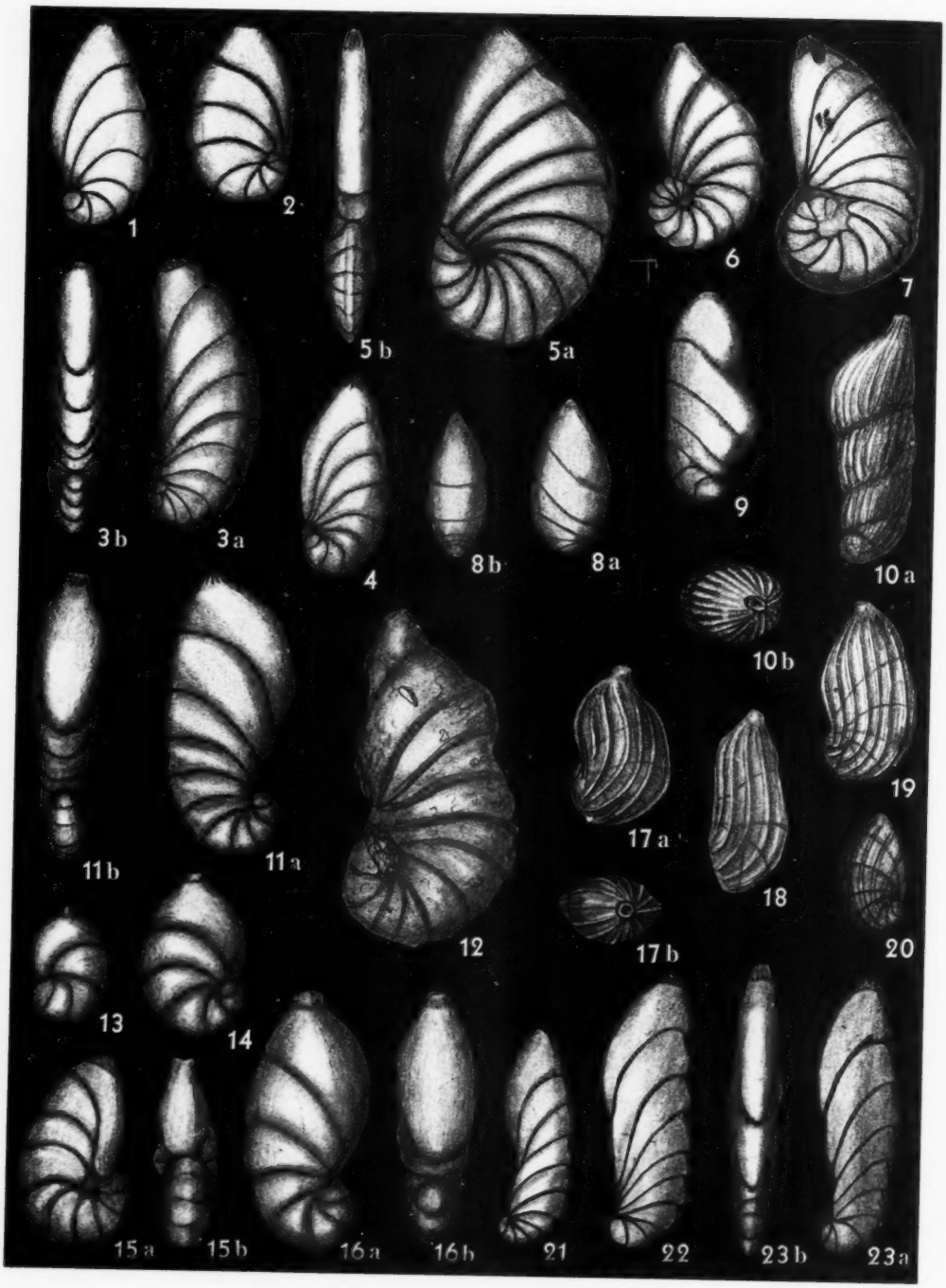
16a–b—*Verneuilinoides tryphera* Loeblich and Tappan, n. sp. *16a*, side view of holotype (USNM 104932), showing inflated chambers and subtriangular outline; *16b*, top view; ×146. (p. 42)

17a–b—*Ammobaculites imlayi* Loeblich and Tappan, n. sp. *17a*, side view of holotype (USNM 104930) showing uniserial portion with breadth about equal to that of coil; *17b*, edge view, showing compressed coil and sub-cylindrical uniserial chambers; ×64. (p. 42)

18a–21b—*Lenticulina audax* Loeblich and Tappan, n. sp. *18a*, side view of holotype (USNM 104936), showing numerous chambers and peripheral keel; *18b*, edge view; *19*, side view of small paratype (USNM 104938a); *20*, side view of small paratype (USNM 104937) showing early development of keel; *21a*, side view of small paratype (USNM 104938b); *21b*, edge view; all ×28. (p. 43)



Loeblich and Tappan, Jurassic Foraminifera



Loeblich and Tappan, Jurassic Foraminifera

104945), figured paratypes (USNM 104946 a–b) and unfigured paratypes (USNM 104947) from Sample J-50 c; unfigured paratypes (USNM 104948) from Sample J-50 e.

Remarks.—*Astacolus agalmatus*, n. sp., is similar in form to large, well-developed specimens of *Cristellaria centro-gyrata* Terquem, but averages over three times as large, and has more numerous chambers. It is quite similar in form to *Cristellaria compressiformis* Paalzow, but is about one-fourth smaller, and the uncoiled portion is more compressed. It is distinguished from *Cristellaria opercula* Crick and Sherborn in being about one-half as large and in having approximately one-third more chambers in the last volution.

ASTACOLUS APHRASTUS Loeblich and Tappan, n. sp.
Plate 12, figures 1–4

Test free, auriculate in outline, compressed, coiled in the early portion, later part uncoiling with the later chambers reaching back nearly to the proloculum, periphery subacute, with a faint keel at the dorsal margin; chambers low and elongate, as many as 12 in well-developed specimens; sutures distinct, somewhat thickened, gently curved; wall calcareous, perforate; aperture radiate, at the dorsal angle.

Greatest length of holotype 0.81 mm., greatest breadth 0.29 mm., greatest thickness 0.10 mm. Other specimens are from 0.31 mm. to 0.81 mm. in length.

Types and occurrence.—Holotype (USNM 104941), figured paratypes (USNM 104942 a–b) and unfigured paratypes (USNM 104944) from Sample J-50 c; figured paratype (USNM 104943) from Sample J-50 a.

Remarks.—*Astacolus aphrastus*, n. sp. is similar to *Cristellaria anceps* Terquem, but specimens with the same number of chambers are nearly twice as large as those of *C. anceps*. The present species differs from *Cristellaria centro-gyrata* Terquem in the less well developed coil, and in being approximately one-third smaller. It is similar to *Cristellaria instabilis* Terquem, but averages one-third larger and has a more regular chamber arrangement.

EXPLANATION OF PLATE 12

FIGS. *1–4*—*Astacolus aphrastus* Loeblich and Tappan, n. sp. *1*, side view of paratype (USNM 104942a); *2*, side view of paratype (USNM 104943); *3a*, side view of holotype (USNM 104941), showing well-developed uncoiled portion and peripheral keel; *3b*, edge view; *4*, side view of paratype (USNM 104942b); all ×48. (p. 45)

5a–7—*Astacolus agalmatus* Loeblich and Tappan, n. sp. *5a*, side view of holotype (USNM 104945), showing large size, numerous low chambers and slight peripheral keel; *5b*, edge view, showing lenticular coil and much compressed uncoiled portion; *6*, side view of paratype (USNM 104946a); *7*, side view of paratype (USNM 104946b); all ×28. (p. 44)

8a–9—*Marginulina erromena* Loeblich and Tappan, n. sp. *8a*, side view of holotype (USNM 104961), showing short, thick test, *8b*, edge view; *9*, side view of paratype (USNM 104962); all ×48. (p. 46)

10a–b—*Marginulina caelata* Loeblich and Tappan, n. sp. *10a*, side view of holotype (USNM 104960), showing acuminate final chamber and numerous fine costae; *10b*, top view, showing rounded cross section; ×106. (p. 46)

11a–16b—*Vaginulinopsis enodis* Loeblich and Tappan, n. sp. *11a*, side view of holotype (USNM 104953), showing small coil and well-developed uncoiled portion; *11b*, edge view, showing compressed character, ×48; *12*, side view of large paratype (USNM 104955a) with somewhat eroded surface, ×48; *13*, side view of small paratype (USNM 104954) showing only the coil, ×64; *14*, side view of paratype (USNM 104956a), ×64; *15a*, side view of paratype (USNM 104955b); *15b*, edge view, ×48; *16a*, side view of paratype (USNM 104956b) showing early development of uncoiled portion; *16b*, edge view, ×64. (p. 46)

17a–20—*Vaginulinopsis ectypa* Loeblich and Tappan, n. sp. *17a*, side view of holotype (USNM 104951), showing obscure sutures and longitudinal costae; *17b*, top view, showing slight degree of compression; *18*, side view of paratype (USNM 104952a); *19*, side view of paratype (USNM 104952b); *20*, side view of small paratype (USNM 104952c); all ×106. (p. 46)

21–23b—*Vaginulinopsis epicharis* Loeblich and Tappan, n. sp. *21*, side view of paratype (USNM 104958a), showing tiny coil and well-developed uniserial portion; *22*, side view of large paratype (USNM 104958b); *23a*, side view of holotype (USNM 104957), showing broad and low chambers and slight peripheral keel; *23b*, edge view, showing compressed character of test; all ×64. (p. 47)

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA CAELATA Loeblich and Tappan, n. sp.
Plate 12, figures 10 a–b

Test free, tiny, elongate, early portion arcuate, later uncoiling and rounded in section; chambers increasing gradually in size, about five in the adult specimen; sutures distinct, slightly depressed, oblique, highest dorsally; wall calcareous, perforate, surface ornamented with numerous very fine costae, about 23 in number; aperture terminal, at the end of a short neck.

Length of holotype 0.34 mm., greatest breadth 0.13 mm., greatest thickness 0.10 mm.

Types and occurrence.—Holotype (USNM 104960) from Sample J-50 a; unfigured paratype (USNM 104950) from Sample J-50 d.

Remarks.—*Marginulina caelata*, n. sp., is similar in form to *Marginulinopsis densicostata* Thalmann, but is only one-seventh as large. It may be distinguished from *Marginulina bifurcata* d'Orbigny by the less prominent ribbing, and from *M. disparilis* Terquem by the much smaller size, more prominent coil and greater breadth. It is distinguished from *M. obliquestriata* Karrer by the oblique sutures, and from *M. radiata* Terquem by the finer and more numerous ribs, and much smaller size.

MARGINULINA ERROMENA Loeblich and Tappan, n. sp.
Plate 12, figures 8a–9

Test free, elongate, early portion arcuate, later chambers uncoiling and rounded in section; chambers numerous, low and broad, six to seven in mature specimens, increasing rapidly in size at first, later more gradually; sutures distinct, nearly straight, oblique, highest dorsally; wall calcareous, perforate, surface smooth; aperture radiate, at the dorsal angle.

Length of holotype 0.42 mm., greatest breadth 0.21 mm., greatest thickness 0.18 mm. Other specimens are from 0.26 mm. to 0.60 mm. in length.

Types and occurrence.—Holotype (USNM 104961) and unfigured paratype (USNM 104949) from Sample J-50 g; figured paratype (USNM 104962) from Sample J-50 d.

Remarks.—*Marginulina erromena*, n. sp., is distinguished from *M. elongata* d'Orbigny by its much smaller size and more oblique sutures. It is only one-half as large as *M. (Psecadium) hamuloides* Brotzen, is more oval in cross section, and has more oblique sutures. It is also similar to *M. hamulus* Chapman, but lacks the acuminate end of that species, is of smaller size and has fewer chambers.

Genus VAGINULINOPSIS Silvestri, 1904
VAGINULINOPSIS ECTYPA Loeblich and Tappan, n. sp.
Plate 12, figures 17a–20

Test free, tiny, compressed, auriculate in outline, periphery subacute; chambers numerous, increasing gradually in size as added, as many as eight in the adult; sutures distinct, gently curved; wall calcareous, perforate, surface ornamented by numerous fine costae, about 13 to 14 in number; aperture simple, terminal, at the end of a short neck.

Length of holotype 0.21 mm., greatest breadth 0.13 mm., greatest thickness 0.08 mm. Other specimens are from 0.21 mm. to 0.36 mm. in length.

Types and occurrence.—Holotype (USNM 104951) and figured paratypes (USNM 104952 a–c) from Sample J-50 a.

Remarks.—*Vaginulinopsis ectypa*, n. sp., differs from *Cristellaria lacunata* Terquem and Berthelin in being about one-fifth as large, and in having more numerous ribs. It differs from *Cristellaria nexa* Terquem and Berthelin in being about one-half as large, and in having more abundant and regular ribbing.

VAGINULINOPSIS ENODIS Loeblich and Tappan, n. sp.
Plate 12, figures 11a–16b

Test free, large, compressed, early portion close-coiled, later portion uncoiling, periphery rounded; chambers numerous, seven or eight in the coil, followed by as many as four or five uncoiled chambers; sutures distinct, somewhat depressed, slightly curved backwards on the periphery; wall calcareous, finely perforate, surface smooth; aperture radiate, at the end of a short neck.

Length of holotype 0.86 mm., greatest breadth of coil 0.31 mm., greatest breadth of uncoiled portion 0.39 mm., greatest thickness 0.18 mm. Other specimens are from 0.26 mm. to 0.99 mm. in length.

Types and occurrence.—Holotype (USNM 104953) from Sample J-50 e; figured paratypes (USNM 104954) from Sample J-50 b, (USNM 104955 a–b) from Sample J-50 c, (USNM 104956 a–b) from Sample J-50 d.

Remarks.—*Vaginulinopsis enodis*, n. sp., is distinguished from *Cristellaria desorii* Kübler and Zwingli in being approximately twice as large, and in having depressed rather than limbate sutures. *Cristellaria jurassica* Gümbel is a similar but slightly larger species, has fewer chambers and a more pronounced neck. *C. jurassica oxfordiana* Deecke has straight oblique sutures, instead of the arched oblique sutures of *V. enodis*.

VAGINULINOPSIS EPICHARIS Loeblich and Tappan, n. sp.
Plate 12, figures 21–23b

Test free, elongate, flattened, early portion close-coiled, later portion uncoiling, periphery subacute; chambers numerous, five or six in the coil, followed by five to six uncoiled chambers; sutures distinct, depressed, strongly oblique, reaching nearly to the coil on the ventral margin, somewhat recurved on the dorsal margin; wall calcareous, finely perforate, surface smooth; aperture radiate, at the dorsal angle.

Length of holotype 0.65 mm., greatest breadth 0.18 mm., greatest thickness 0.08 mm. Other specimens are from 0.31 mm. to 0.81 mm. in length.

Types and occurrence.—Holotype (USNM 104957), figured paratypes (USNM 104958 a–b) and unfigured paratypes (USNM 104959) from Sample J-50 f.

Remarks.—*Vaginulinopsis epicharis*, n. sp., may be distinguished from *Cristellaria centralis* Terquem by the less prominent coil and narrower test. It is about one-fourth larger than *Cristellaria centro-gyrata* Terquem and the test is narrower. It may be separated from *Cristellaria instabilis* Terquem by the absence of ribbing and from *Cristellaria prava* Terquem by being about one-half as large.

Genus DENTALINA d'Orbigny, 1826

DENTALINA BRACHISTA Loeblich and Tappan, n. sp.
Plate 13, figure 1

Test free, elongate, robust; chambers increasing gradually in size as added, last chamber about twice as high as the preceding chamber, generally about four chambers present; sutures distinct, straight, slightly depressed, so that the test is constricted at the sutures; wall calcareous, finely perforate, surface smooth; aperture radiate, terminal.

Length of holotype 0.73 mm., greatest breadth 0.23 mm.; other specimens are from 0.44 mm. to 0.73 mm. in length.

Types and occurrence.—Holotype (USNM 104968) and unfigured paratypes (USNM 104969) from Sample J-50 d.

Remarks.—*Dentalina brachista*, n. sp., may be separated from *D. bullata* Schwager by being about three times as large, and by having less inflated chambers. It is only one-half as large as *D. chrysalis* Kübler and Zwingli or *D. gottingensis* Franke, and lacks the acuminate end of the latter. It may be distinguished from *D. paalzowiana* Kuhn by being approximately twice as large.

DENTALINA ECTADIA Loeblich and Tappan, n. sp.
Plate 13, figures 3–5

Test free, large, arcuate; chambers increasing gradually in size from the rounded base, as many as eight in mature specimens, last chamber nearly twice the length of the preceding chamber, chambers slightly inflated centrally and constricted at the sutures; sutures distinct, depressed, oblique; wall calcareous, finely perforate, surface smooth; aperture radiate, produced on a short neck.

Length of holotype 1.51 mm., greatest breadth 0.31 mm. Other specimens are from 0.34 mm. to 1.82 mm. in length.

Types and occurrence.—Holotype (USNM 104963) and figured paratypes (USNM 104964) from Sample J-50 c; figured paratype (USNM 104965) and unfigured paratypes (USNM 104966) from Sample J-50 b.

Remarks.—*Dentalina ectadia*, n. sp., differs from *D. funiculus* Schwager in being approximately one-half as large, in having

less oblique sutures and in lacking the acuminate end of that species. It is similar to *D. intermedia* Reuss, but is smaller in size, with less oblique sutures, and a more bulbous initial portion. It is three times as large as *D. oppeli* Schwager and may be separated from *D. pseudocommunis* Franke by the larger size, more inflated chambers and depressed sutures.

DENTALINA EJUNCIDA Loeblich and Tappan, n. sp.
Plate 13, figures 9–11

Test free, tiny, elongate, slender, slightly arcuate; consisting of numerous chambers which increase gradually in size as added, last chamber about $1\frac{1}{4}$ times as long as the previous chamber, as many as 11 chambers in well-developed specimens; sutures distinct, straight, somewhat oblique, slightly depressed, so that the test is somewhat constricted at the sutures; wall calcareous, finely perforate, surface smooth; aperture radiate, at the end of a short neck.

Length of holotype 0.44 mm., greatest breadth 0.08 mm. Other specimens are from 0.36 mm. to 0.62 mm. in length.

Types and occurrence.—Holotype (USNM 104970), figured paratypes (USNM 104971 a–b) and unfigured paratypes (USNM 104972) from Sample J-50 d.

Remarks.—*Dentalina ejuncida*, n. sp., is similar to *D. extensa* Schwager, but is slightly larger in size, has more regularly enlarging chambers and a more pronounced terminal neck. The present species may be differentiated from *D. gümbeli* Schwager by its less arcuate test and more oblique sutures.

DENTALINA LEPTOSYNA Loeblich and Tappan, n. sp.
Plate 13, figure 2

Test free, elongate, nearly straight; composed of about eight low chambers, increasing slowly in size from the rounded base; sutures distinct, oblique, but not much depressed, so that the test is subcylindrical; wall calcareous, finely perforate, surface smooth; aperture radiate, terminal.

Length of holotype 1.07 mm., greatest breadth 0.21 mm.; other specimens from 0.57 mm. to 1.40 mm. in length.

Types and occurrence.—Holotype (USNM 104967) from Sample J-50 d.

Remarks.—*Dentalina leptosyna*, n. sp., is distinguished from *D. gladiiformis* Franke by its smaller size, less tapering test and acuminate final chamber.

DENTALINA LIOTA Loeblich and Tappan, n. sp.
Plate 14, figures 13–14

Test free, elongate, robust, slightly arcuate; chambers increasing gradually in size from the pointed base, at first low and broad, later chambers of greater proportional height, generally six to seven chambers in adult tests; sutures distinct, slightly depressed; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Length of holotype 0.78 mm., greatest breadth 0.21 mm. Other specimens are from 0.42 mm. to 0.78 mm. in length.

Types and occurrence.—Holotype (USNM 104973), figured paratype (USNM 104974) and unfigured paratypes (USNM 104975) from Sample J-50 b.

Remarks.—*Dentalina liota*, n. sp., is similar to *D. conferta* Schwager, but has lower chambers, less oblique sutures and a less acuminate initial portion.

Genus NODOSARIA Lamarck, 1812
NODOSARIA AMPHIGYA Loeblich and Tappan, n. sp.
Plate 13, figures 15–16

Test free, small, elongate, rectilinear; chambers elongate-ovate, inflated slightly below the median line, strongly constricted at the sutures; sutures distinct, deeply depressed, so that the fragile tests are generally broken, none found having more than two chambers still intact; wall calcareous, finely perforate, surface ornamented with 18 to 20 low longitudinal ribs; aperture terminal, on a slender, elongate neck.

Length of holotype 0.36 mm., greatest breadth 0.10 mm.; other specimens from 0.23 mm. to 0.36 mm. in length.

Types and occurrence.—Holotype (USNM 104984) from Sample J-50 d; figured paratype (USNM 104985) from Sample J-50 b.

Remarks.—*Nodosaria amphigya*, n. sp., differs from *Dentalina notabilis* Terquem and Berthelin in being approximately one-third

smaller and in having depressed and clearly distinct sutures.

NODOSARIA BALTEATA Loeblich and Tappan, n. sp.
Plate 13, figures 6–8

Test free, tiny, rectilinear, elongate; chambers numerous, at first increasing rapidly in diameter, later chambers showing very little increase in diameter, but last chamber about twice as long as that preceding; sutures distinct, straight, slightly depressed; wall calcareous, finely perforate, surface ornamented with about 14 low longitudinal ribs; aperture simple, terminal.

Length of holotype 0.26 mm., greatest breadth 0.08 mm.; other specimens from 0.23 mm. to 0.34 mm. in length.

Types and occurrence.—Holotype (USNM 104981) from Sample J-50 a; figured paratypes (USNM 104982 a–b) and unfigured paratypes (USNM 104983) from Sample J-50 b.

Remarks.—*Nodosaria balteata*, n. sp., is distinguished from *N. bambergensis* Franke in being approximately one-third as large, and having lower chambers. It differs from *N. issleri* Franke by having nearly twice as many ribs, and is less than one-third the size of *N. issleri*. The present species is one-half as large as *N. opalini* Bartenstein and has a less acuminate initial portion.

NODOSARIA DAEDALA Loeblich and Tappan, n. sp.
Plate 13, figures 18–19

Test free, elongate, rectilinear, tapering; chambers numerous, low and broad, increasing rather rapidly in size as added, slightly inflated centrally, about six in the average specimen; sutures distinct, somewhat constricted; wall calcareous, finely perforate, surface ornamented by about 14 low costae; aperture terminal.

Length of holotype 0.57 mm., greatest breadth 0.21 mm.; other specimens from 0.44 mm. to 0.68 mm. in length.

Types and occurrence.—Holotype (USNM 104978) from Sample J-50 e; figured paratype (USNM 104979) from Sample J-50 a; unfigured paratype (USNM 104980) from Sample J-50 b.

Remarks.—*Nodosaria daedala*, n. sp., may be separated from *Dentalina demissa* Terquem and Berthelin by its larger size, lower chambers and more abundant ribbing, and it may be distinguished from *Dentalina oculina* Terquem and Berthelin by being approximately twice as large and by having more numerous costae.

NODOSARIA LIRULATA Loeblich and Tappan, n. sp.
Plate 13, figures 12–14

Test free, elongate, rectilinear, robust, strongly constricted at the sutures; chambers subglobular, seldom more than three in a specimen because of the fragile character of the test, the deep constrictions between chambers causing the test to break easily at these points; sutures distinct, depressed, straight; wall calcareous, finely perforate; surface ornamented by about 13 fairly coarse ribs; aperture terminal, simple.

Length of holotype 0.60 mm., greatest breadth 0.23 mm.; other specimens from 0.26 mm. to 0.60 mm. in length.

Types and occurrence.—Holotype (USNM 104976) and figured paratypes (USNM 104977 a–b) from Sample J-50 a.

Remarks.—*Nodosaria lirulata*, n. sp., differs from *Dentalina egregia* Terquem and Berthelin in being three times as large; it agrees in size with *Dentalina annulata* Terquem, but has more bulbous chambers and more numerous ribs; it differs from *Dentalina crassicostata* Terquem in the less incised chambers and more numerous ribs; it is separated from *Nodosaria corallina* Gümbel by the more abundant ribs and from *N. multicosta* Terquem and Berthelin by the coarser ribs, larger size, and less pronounced neck.

NODOSARIA MECISTA Loeblich and Tappan, n. sp.
Plate 13, figures 17, 20–22

Test free, narrow and elongate, tapering, mature specimens generally represented only by broken segments of the slender and delicate tests; chambers numerous, increasing very gradually in size from the rounded proloculum, slightly inflated centrally, final chamber subpyriform, tapering toward the aperture; sutures distinct, straight, depressed; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Length of holotype 1.07 mm., greatest

breadth 0.23 mm.; other specimens from 0.44 to 1.46 mm. in length.

Types and occurrence.—Holotype (USNM 104986) from Sample J-50 c; figured paratypes (USNM 104987) from Sample J-50 b, (USNM 104988) from Sample J-50 e, and (USNM 104989) from Sample J-50 d.

Remarks.—*Nodosaria mecista*, n. sp., differs from *N. candela* Franke in the more tapering test, slightly lower chambers and more distinct sutures, and from *N. germanica* Franke in the tapering test, lower chambers, and in lacking the acuminate initial portion of *N. germanica*. *Nodosaria lepida* Reuss has more inflated chambers and depressed sutures, whereas *N. nitida elongata* Franke is a similar species, but about one-third larger and with somewhat higher chambers. *Nodosaria mecista* is also similar to *N. waageni* Schwager, but the latter species is approximately one-third larger.

Genus PSEUDOGLANDULINA
Cushman, 1929
PSEUDOGLANDULINA TRAPHERA Loeblich and Tappan, n. sp.
Plate 13, figure 23

Test free, elongate, rectilinear, robust; chambers numerous, as many as six in mature specimens, of somewhat greater breadth than height; sutures distinct, somewhat constricted; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Length of holotype 0.73 mm., greatest breadth 0.23 mm.; other specimens observed are up to 0.73 mm. in length.

Types and occurrence.—Holotype (USNM 104990) from Sample J-50 e; unfigured paratypes (USNM 104991) from Sample J-50 d.

Remarks.—*Pseudoglandulina traphera*, n. sp., is similar to *P. scotti* Tappan, but differs in possessing a more robust and less tapering test.

Genus LINGULINA d'Orbigny, 1826
LINGULINA AMPLIATA Loeblich and Tappan, n. sp.
Plate 13, figures 25a–26b

Test free, small, subtriangular in outline, strongly compressed, margins subacute; equitant chambers increasing more rapidly in breadth than height from the rounded proloculum, so that later chambers are about three times as broad as they are high; sutures distinct, depressed, arched centrally; wall calcareous, finely perforate, surface smooth; aperture terminal, elongate.

Length of holotype 0.23 mm., greatest breadth 0.13 mm., greatest thickness 0.04 mm. Other specimens are from 0.18 mm. to 0.29 mm. in length.

Types and occurrence.—Holotype (USNM 105000) and unfigured paratype (USNM 105003) from Sample J-50 e; figured paratype (USNM 105001) from Sample J-50 c; unfigured paratype (USNM 105002) from Sample J-50 d.

Remarks.—*Lingulina ampliata*, n. sp., differs from *L. dentaliniformis* Terquem and *Lingulina furcillata* Berthelin in having a more flaring test, and a rounded rather than slitlike aperture. It is about one-third smaller than *L. lamellata* Tappan, and has less highly arched chambers. It may be separated from *Frondicularia dolium* Terquem by the more compressed test, more ovate aperture and by being only one-half as large.

LINGULINA CAMERATA Loeblich and Tappan, n. sp.
Plate 13, figures 28a–b

Test free, small, broad and elongate, strongly compressed, margins subacute; equitant chambers increasing gradually in breadth from the rounded proloculum, increasing very little in height; sutures distinct, depressed, highly arched centrally; wall calcareous, finely perforate, surface smooth; aperture terminal, elongate.

Length of holotype 0.34 mm., greatest breadth 0.10 mm., greatest thickness 0.05 mm. Other specimens are from 0.26 mm. to 0.34 mm. in length.

Types and occurrence.—Holotype (USNM 104998) from Sample J-50 b; unfigured paratype (USNM 104999) from Sample J-50 c.

Remarks.—*Lingulina camerata*, n. sp., differs from *L. dentaliniformis* Terquem in being about one-third smaller, and in having more highly arched sutures. It is separated from *L. furcillata* Berthelin by its smaller size, lower chambers, and rounded rather than slitlike aperture. It is approximately

one-half the size of *L. praelonga* ten Dam and has a slightly more flaring test.

LINGULINA LORDOSA Loeblich and Tappan, n. sp.
Plate 13, figures 24a–b

Test free, large, robust, rectilinear, flattened, with a slight longitudinal central depression; margins subacute; chambers increasing gradually in breadth as added, increasing more slowly in height, so that later chambers are nearly three times as broad as they are high; sutures distinct, arched centrally; wall calcareous, finely perforate, surface smooth; aperture terminal, on a short neck, and in well-preserved specimens showing a radial character.

Length of holotype 0.78 mm., greatest breadth 0.34 mm., greatest thickness 0.23 mm.; other specimens from 0.47 mm. to 0.78 mm. in length.

Types and occurrence.—Holotype (USNM 104992) and unfigured paratypes (USNM 104993) from Sample J-50 a.

Remarks.—*Lingulina lordosa*, n. sp., may be distinguished from *L. cordiformis* Terquem by being approximately one-third smaller, in lacking the very large terminal chamber, which in the type of *L. cordiformis* has a height greater than the preceding three chambers combined. *L. lordosa* differs from *L. cordiformis* in possessing a radial aperture on a short neck, rather than an elongate aperture. The present species may be separated from *L. gottingensis* Franke by the compressed rather than inflated test, and in having arched instead of straight sutures. It is separated from *Frondicularia excavata* Terquem by its much larger size, radiate aperture and less strongly arched sutures.

LINGULINA MICIDA Loeblich and Tappan, n. sp.
Plate 13, figures 29a–30b

Test free, small, narrow and elongate, slightly compressed, margins subrounded; chambers numerous, as many as eight in adult specimens, at first broad and low, increasing in proportionate height as added; sutures distinct, depressed, somewhat arched centrally; wall calcareous, finely perforate, surface smooth; aperture terminal, somewhat elongate.

Length of holotype 0.49 mm., greatest breadth 0.10 mm., greatest thickness 0.05 mm. Other specimens are from 0.23 mm. to 0.49 mm. in length.

Types and occurrence.—Holotype (USNM 104994) from Sample J-50 d; figured paratype (USNM 104995) and unfigured paratypes (USNM 104996) from Sample J-50 c; unfigured paratype (USNM 104997) from Sample J-50 f.

Remarks.—*Lingulina micida*, n. sp., differs from *L. dentaliniformis* Terquem in being less compressed and in having a rounded rather than slitlike aperture. It may be differentiated from *L. nodosaria* Reuss by its smaller size, and more highly arched sutures. It is one-third smaller than *Frondicularia longiscata* Terquem and lacks the centrally thickened sutures of that species.

LINGULINA TUMIDA Loeblich and Tappan, n. sp.
Plate 13, figures 27a–b

Test free, small, elongate, uniserial, slightly compressed, robust; about seven chambers, increasing gradually in size as added, later chambers showing almost no increase in size, so that the sides of the tests are subparallel, chamber breadth somewhat greater than height; sutures distinct, depressed, straight; wall calcareous, finely perforate, surface smooth; aperture terminal, elongate.

Length of holotype 0.34 mm., greatest breadth 0.13 mm., greatest thickness 0.08 mm. Other specimens are from 0.31 mm. to 0.42 mm. in length.

Types and occurrence.—Holotype (USNM 105004) from Sample J-50 d; unfigured paratypes (USNM 105005, 105006) from Sample J-50 e.

Remarks.—*Lingulina tumida*, n. sp., differs from *L. dentaliniformis* Terquem in being about one-third smaller, in having a less compressed test and an oval rather than slitlike aperture. It differs from *L. ovalis* Schwager in being one-third larger and more rounded in cross section, and from *L. ovalis* Terquem and Berthelin in being one-third smaller and in having an ovate rather than slitlike aperture.

Genus TRISTIX Macfadyen, 1941

TRISTIX ALCIMA Loeblich and Tappan, n. sp.

Plate 14, figures 6a–b

Test free, uniserial, triangular in section, robust, somewhat tapered at the base, later portion with subparallel sides; sides moderately excavated, angles subacute; chambers numerous, about eight in well-developed specimens; sutures distinct, arched upwards at the center of the faces, curved downward at the angles; wall calcareous, finely perforate, surface smooth; aperture terminal, rounded.

Length of holotype 0.55 mm., greatest breadth of a side 0.26 mm., thickness from

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EXPLANATION OF PLATE 13

FIG. *1*—*Dentalina brachista* Loeblich and Tappan, n. sp. Holotype (USNM 104968) showing short, broad test, ×48. (p. 47)

2—*Dentalina leptosyna* Loeblich and Tappan, n. sp. Holotype (USNM 104967) showing tapering test, oblique sutures, and acuminate final chamber, ×48. (p. 48)

3–5—*Dentalina ectadia* Loeblich and Tappan, n. sp. *3*, paratype (USNM 104965) showing rounded base, subcylindrical chambers and slight neck; *4*, large incomplete paratype (USNM 104964) showing great size attained by this species; *5*, holotype (USNM 104963, showing large test, and elongate final chamber; all ×48. (p. 47)

6–8—*Nodosaria balteata* Loeblich and Tappan, n. sp. *6*, holotype (USNM 104981) showing broad and low chambers and elongate, sub-pyriform final chamber; *7*, small paratype (USNM 104982a); *8*, large paratype (USNM 104982b) showing tapered base and very slight increase in diameter of later chambers; all ×106. (p. 49)

9–11—*Dentalina ejuncida* Loeblich and Tappan, n. sp. *9*, incomplete paratype (USNM 104971a) showing maximum chamber size attained by this species; *10*, holotype (USNM 104970) showing small size and gradually tapering test; *11*, small paratype (USNM 104971b); all ×48. (p. 48)

12–14—*Nodosaria lirulata* Loeblich and Tappan, n. sp. *12*, paratype (USNM 104977a) showing incomplete specimen, due to fragile character of the test; *13*, holotype (USNM 104976) showing low chambers, constricted sutures and coarse ribs; *14*, paratype (USNM 104977b) showing slight increase in chamber size; all ×48. (p. 49)

15–16—*Nodosaria amphigya* Loeblich and Tappan, n. sp. *15*, small paratype (USNM 104985) showing narrow elongate chambers; *16*, holotype (USNM 104984) showing pointed base, numerous fine costae and slender neck; ×106. (p. 48)

17, 20–22—*Nodosaria mecista* Loeblich and Tappan, n. sp. *17*, paratype (USNM 104987) showing small form with rounded proloculum, subcylindrical chambers and subpyriform final chamber, ×106; *20*, holotype (USNM 104986) showing large size attained by this species, ×48; *21*, paratype (USNM 104989) showing tapering base, ×48; *22*, paratype (USNM 104988) showing small individual, ×48. (p. 49)

18–19—*Nodosaria daedala* Loeblich and Tappan, n. sp. *18*, holotype (USNM 104978) showing stout test, low chambers and strong costae; *19*, paratype (USNM 104979) showing a more tapering individual; ×48. (p. 49)

23—*Pseudoglandulina traphera* Loeblich and Tappan, n. sp. Holotype (USNM 104990) showing subcylindrical chambers and robust test, ×48. (p. 50)

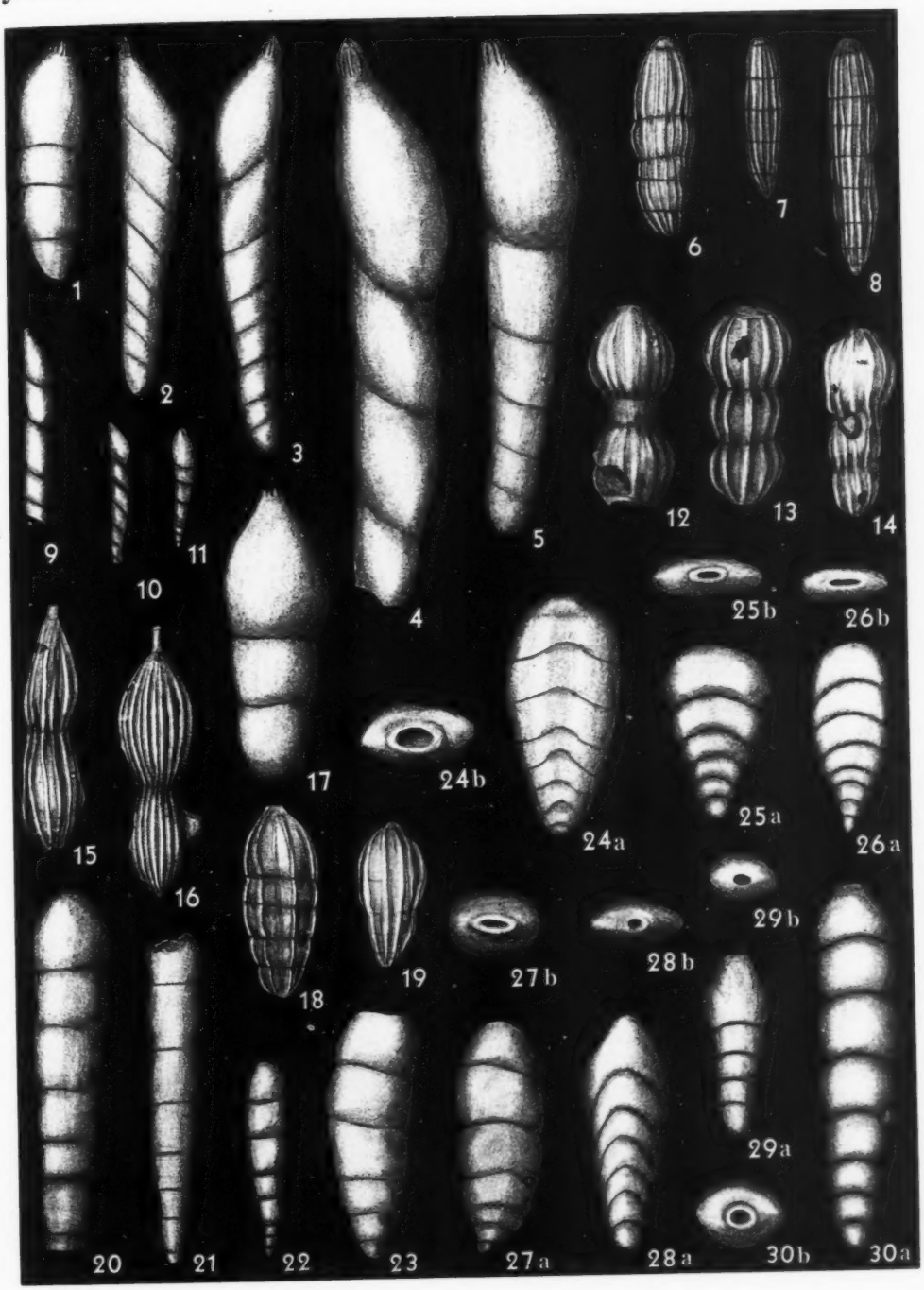
24a–b—*Lingulina lordosa* Loeblich and Tappan, n. sp. *24a*, side view of holotype (USNM 104992), showing slight longitudinal central depression of test, and chevron-shaped chambers; *24b*, top view, showing subacute margins and short neck. Some fragmentary specimens show a distinct radial aperture, but as this portion is broken from the holotype, only the somewhat elongate neck is visible; ×48. (p. 51)

25a–26b—*Lingulina ampliata* Loeblich and Tappan, n. sp. *25a*, side view of holotype (USNM 105000), showing subtriangular outline and gently arched sutures; *25b*, top view, showing compression and elongate aperture; *26a*, side view of paratype (USNM 105001) showing a more tapered base; *26b*, top view; all ×106. (p. 50)

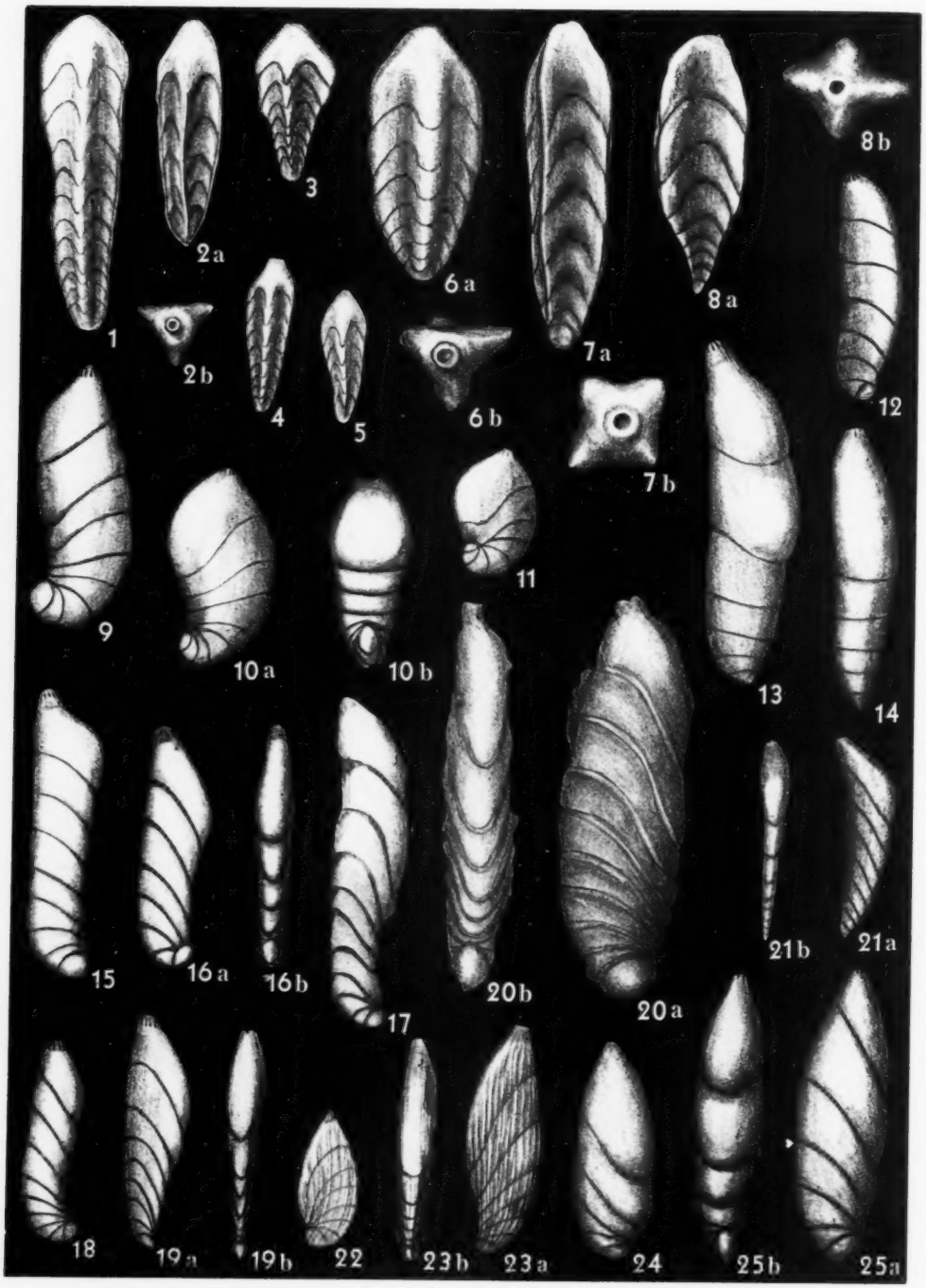
27a–b—*Lingulina tumida* Loeblich and Tappan, n. sp. *27a*, side view of holotype (USNM 105004), showing stout test and subcylindrical chambers; *27b*, top view, showing slight degree of compression and elongate aperture, ×106. (p. 51)

28a–b—*Lingulina camerata* Loeblich and Tappan, n. sp. *28a*, side view of holotype (USNM 104998) showing elongate test and highly arched sutures; *28b*, top view, showing subacute margins and sub-rounded aperture; ×106. (p. 50)

29a–30b—*Lingulina micida* Loeblich and Tappan, n. sp. *29a*, side view of paratype (USNM 104995), showing small form, slightly tapered test and very slightly arched sutures; *29b*, top view, showing slight degree of compression and suboval aperture; *30a*, side view of holotype (USNM 104994), showing narrow elongate form and subpyriform final chamber; *30b*, top view; all ×106. (p. 51)



Loeblich and Tappan, Jurassic Foraminifera



Loeblich and Tappan, Jurassic Foraminifera

center of a side through the opposite angle 0.18 mm. Other specimens are from 0.23 mm. to 0.60 mm. in length.

Types and occurrence.—Holotype (USNM 105007) and unfigured paratypes (USNM 105008) from Sample J-50 a.

Remarks.—*Tristix alcima*, n. sp., differs from *Rhabdogonium excavatum* Reuss in being about one-third smaller and in having more rounded angles and less deeply excavated sides.

TRISTIX REESIDEI Loeblich and Tappan, n.sp.
Plate 14, figures 1–5

Test free, narrow, elongate, tapering gradually, triangular in section, sides moderately excavated, angles acute; chambers increasing gradually in size as added, as many as 12 in well-developed specimens; sutures distinct, highly arched at the center of the faces, curving downward at the angles of the test; wall calcareous, finely perforate, surface smooth; aperture terminal, rounded.

Length of holotype 0.49 mm., greatest breadth of side 0.18 mm., greatest thickness from center of a side through the opposite angle 0.13 mm. Other specimens are from 0.18 mm. to 0.70 mm. in length.

Types and occurrence.—Holotype (USNM 105009), and figured paratype (USNM 105019) from Sample J-50 b; figured paratypes (USNM 105011 a–c) from Sample J-50 e; unfigured paratypes (USNM 105012) from Sample J-50 c.

Remarks.—*Tristix reesidei*, n. sp., differs

EXPLANATION OF PLATE 14

FIGS. *1–5*—*Tristix reesidei* Loeblich and Tappan, n. sp. *1*, side view of paratype (USNM 105011a), showing very elongate form; *2a*, side view of holotype (USNM 105009), showing arched sutures, acute angles and pointed base; *2b*, top view, showing triangular section, acute angles and rounded aperture; *3*, side view of paratype (USNM 105011b), showing tapered base; *4*, side view of paratype (USNM 105011c); *5*, side view of small paratype (USNM 105010) all ×64. (p. 53)

6a–b—*Tristix alcima* Loeblich and Tappan, n. sp. *6a*, holotype (USNM 105007) showing robust form and subtriangular outline; *6b*, top view, showing subacute angles and rounded aperture; ×64. (p. 52)

7a–b—*Quadratina inornata* Loeblich and Tappan, n. sp. *7a*, side view of holotype (USNM 105013), showing rounded base and moderately excavated sides; *7b*, top view, showing quadrate section, subacute angles and rounded aperture; ×64. (p. 54)

8a–b—*Quadratina juncta* Loeblich and Tappan, n. sp. *8a*, side view of holotype (USNM 105017), showing pointed base and moderately excavated sides; *8b*, top view, showing quadrate section and rounded aperture; ×106. (p. 54)

9–11—*Saracenaria cypha* Loeblich and Tappan, n. sp. *9*, paratype (USNM 105022) showing early coil and well developed uncoiled portion; *10a*, side view of holotype (USNM 105020); *10b* face view, showing wide apertural face; *11*, side view of paratype (USNM 105021); all ×48. (p. 54)

12—*Vaginulina formosula* Loeblich and Tappan, n. sp. Holotype (USNM 105030) showing early coil, well-developed uncoiled portion, and straight peripheral margin; ×48. (p. 55)

13–14—*Dentalina liota* Loeblich and Tappan, n. sp. *13*, holotype (USNM 104973) showing robust form and slightly arcuate test; *14*, paratype (USNM 104974) showing smaller form; ×64. (p. 48)

15–19b—*Vaginulina compsa* Loeblich and Tappan, n. sp. *15*, side view of paratype (USNM 105027); *16a*, paratype (USNM 105028a); *16b*, face view, showing compressed character; *17*, paratype (USNM 105028b) showing large form, oblique and slightly curved sutures; *18*, paratype (USNM 105028c) showing small form; *19a*, side view of holotype (USNM 105026), showing low chambers and slightly flaring test; *19b*, edge view; all ×64. (p. 55)

20a–b—*Vaginulina ischyra* Loeblich and Tappan, n. sp. *20a*, holotype (USNM 105031), showing large robust form and thickened sutures; *20b*, face view, showing thick test; ×48. (p. 56)

21a–b—*Vaginulina lechriosa* Loeblich and Tappan, n. sp. *21a*, side view of holotype (USNM 105037), showing subtriangular outline and oblique sutures; *21b*, edge view, showing compressed test; ×64. (p. 56)

22–23b—*Vaginulina cataulaca* Loeblich and Tappan, n. sp. *22*, paratype (USNM 105034) showing subovate outline; *23a*, holotype (USNM 105033) showing well developed specimen with numerous fine ribs; *23b* edge view, ×64. (p. 54)

24–25b—*Vaginulina inspissata* Loeblich and Tappan, n. sp. *24*, paratype (USNM 105040) showing oblique sutures and elongate-ovate outline; *25a*, side view of holotype (USNM 105039), showing slightly curved peripheral margin and acuminate final chamber; *25b*, face view, showing slightly inflated chambers; all ×64. (p. 55)

from *Rhabdogonium excavatum exilis* Chapman in being about one-half as large, and more triangular in section, with less-excavated sides. It differs from *Rhabdogonium liasinum* Berthelin in being almost three times as large, and in having acute rather than rounded angles.

Genus QUADRATINA ten Dam, 1946
QUADRATINA INORNATA Loeblich and Tappan, n. sp.
Plate 14, figures 7a–b

Test free, elongate, quadrate in section, sides subparallel, tapered slightly at the base, faces moderately excavated, angles subacute; chambers numerous, increasing gradually in size from the rounded proloculum, about eight in a mature specimen; sutures distinct, slightly depressed, arched centrally curving downward at the angles of the chambers; wall calcareous, finely perforate, surface smooth; aperture terminal, rounded.

Length of holotype 0.75 mm., greatest breadth of a side 0.21 mm.; other specimens from 0.52 mm. to 0.75 mm. in length.

Types and occurrence.—Holotype (USNM 105013) from Sample J-50 c; unfigured paratype (USNM 105014) from Sample J-50 d.

Remarks.—*Quadratina inornata*, n. sp., may be distinguished from *Rhabdogonium märtensi* Reuss by the less tapering test, and more rounded angles, and from *Quadratina juncta*, n. sp., in being about twice as large, and in having subparallel sides rather than a tapered initial portion.

QUADRATINA JUNCTA Loeblich and Tappan, n. sp.
Plate 14, figures 8a–b

Test free, small, elongate, tapering to the pointed base, quadrate in section, sides moderately excavated, angles acute; about nine chambers present, increasing gradually in size as added; sutures distinct, depressed, strongly arched centrally, curving sharply downward at the chamber angles; wall calcareous, finely perforate, surface smooth; aperture terminal, rounded.

Length of holotype 0.36 mm., greatest breadth of side 0.10 mm.; other specimens from 0.26 mm. to 0.36 mm. in length.

Types and occurrence.—Holotype (USNM 105017) from Sample J-50 f; unfigured paratypes (USNM 105018) from Sample J-50 d and (USNM 105019) from Sample J-50 e.

Remarks.—*Quadratina juncta*, n. sp., may be distinguished from *Rhabdogonium märtensi* Reuss in being about one-half as large, in having a more flaring test in the early portion and in having more rounded angles.

Genus SARACENARIA Defrance, 1824
SARACENARIA CYPHA Loeblich and Tappan, n. sp.
Plate 14, figures 9–11

Test free, robust, early portion coiled, later uncoiling, with test subtriangular in section; chambers increasing gradually in size as added, four to five in the coil, followed by as many as six uncoiled chambers; sutures distinct, depressed; wall calcareous, finely perforate, surface smooth; aperture radiate, at the peripheral angle.

Length of holotype 0.60 mm., greatest diameter of coil 0.21 mm., greatest breadth of uniserial portion 0.31 mm., greatest breadth of apertural face 0.26 mm.

Types and occurrence.—Holotype (USNM 105020), figured paratype (USNM 105021) and unfigured paratypes (USNM 105024) from Sample J-50 f; figured paratypes (USNM 105022) and unfigured paratypes (USNM 105023) from Sample J-50 d; unfigured paratypes (USNM 105025) from Sample J-50 g.

Remarks.—*Saracenaria cypha*, n. sp., may be distinguished from *S. saratogana* Howe and Wallace by being about one-fourth as large, and in having less oblique sutures. It may be distinguished from *Cristellaria* (*Saracenaria*) *hannoverana* Franke as it is only two-thirds the size of that species.

Genus VAGINULINA d'Orbigny, 1826
VAGINULINA CATAULACA Loeblich and Tappan, n. sp.
Plate 14, figures 22–23b

Test free, flattened, subovate in outline, early portion coiled, later uncoiling, with later chambers reaching back nearly to the coil; chambers increasing gradually in size as added, low and broad, about eight in the adult test; sutures distinct, gently curved, highest at the peripheral margin; wall calcareous, finely perforate, surface ornamented with numerous fine ribs, generally

from 10 to 12; aperture radiate, at the peripheral angle.

Length of holotype 0.49 mm., greatest breadth 0.16 mm., greatest thickness 0.07 mm. Other specimens are from 0.21 mm. to 0.62 mm. in length.

Types and occurrence.—Holotype (USNM 105033) and figured paratype (USNM 105034) and unfigured paratype (USNM 105035) from Sample J-50 b; unfigured paratypes (USNM 105036) from Sample J-50 c.

Remarks.—*Vaginulina cataulaca*, n. sp., is distinguished from *Cristellaria intorta* Terquem in being one-half as large and in having many more ribs ornamenting the surface. It differs from *Cristellaria mutabilis* Terquem in being about one-third smaller, in having a less acutely angled periphery and in having more oblique sutures. It is similar to *Vaginulina complanata perstriata* Tappan, but is about one-third smaller and the chambers do not extend as far backward ventrally. It differs from *V. subrotunda* ten Dam in being approximately one-half as large and in having a somewhat narrower test.

VAGINULINA COMPSA Loeblich and Tappan, n. sp.
Plate 14, figures 15–19b

Test free, elongate, flattened, early portion coiled, later portion uncoiling, with peripheral margin straight; chambers numerous, as many as 11 in mature specimens, increasing gradually in size as added; sutures distinct, oblique, slightly curved, highest at the dorsal margin; wall calcareous, finely perforate, surface smooth; aperture radiate, at the peripheral angle.

Length of holotype 0.52 mm., greatest breadth 0.13 mm., greatest thickness 0.08 mm. Other specimens are from 0.34 mm. to 0.91 mm. in length.

Types and occurrence.—Holotype (USNM 105026) from Sample J-50 d; figured paratype (USNM 105027) from Sample J-50 a; figured paratypes (USNM 105028 a–c) and unfigured paratypes (USNM 105029) from Sample J-50 e.

Remarks.—*Vaginulina compsa*, n. sp., differs from *Cristellaria cryptospira* Paalzow in being more compressed, and in having more oblique sutures. It is distinguished from *Cristellaria gryphaea* Kübler and Zwingli by the narrower test and by lacking the limbate sutures of the latter. It is similar to *Vaginulina marginulinoides* Reuss, but is less than one-half as large and has less limbate sutures.

VAGINULINA FORMOSULA Loeblich and Tappan, n. sp.
Plate 14, figure 12

Test free, elongate, slightly compressed, early portion coiled, later uncoiling with peripheral margin straight; chambers increasing gradually in size as added, eight in the holotype; sutures distinct, slightly depressed, oblique, highest at the peripheral margin; wall calcareous, finely perforate, surface smooth; aperture radiate, at the peripheral angle.

Length of holotype 0.68 mm., greatest breadth 0.21 mm., greatest thickness 0.16 mm.

Types and occurrence.—Holotype (USNM 105030) from Sample J-50 c.

Remarks.—*Vaginulina formosula*, n. sp., differs from *V. lingulata* Paalzow in the slightly larger size, less compressed test and less oblique sutures. It differs from *V. parva* Franke by the slightly larger size and less oblique sutures.

VAGINULINA INSPISSATA Loeblich and Tappan, n. sp.
Plate 14, figures 24–25b

Test free, elongate-ovate in outline, somewhat flattened, early portion coiled, later uncoiling, with peripheral margin slightly curved, sides convex; chambers increasing gradually in size as added, six to seven present in the adult, inflated centrally; sutures distinct, depressed, slightly curved backwards at the peripheral margin; wall calcareous, finely perforate, surface smooth; aperture radiate, at the peripheral angle.

Length of holotype 0.68 mm., greatest breadth 0.21 mm., thickness 0.16 mm. Other specimens are from 0.39 mm. to 0.68 mm. in length.

Types and occurrence.—Holotype (USNM 105039), figured paratype (USNM 105040) and unfigured paratypes (USNM 105041) from Sample J-50 b.

Remarks.—*Vaginulina inspissata*, n. sp., differs from *Cristellaria collarifera* Schwager by being about twice as large, in having less

depressed sutures, and in possessing a more rounded ventral face. It differs from *Cristellaria complanata* Schwager in having lower early chambers and in lacking the elongate neck of that species.

VAGINULINA ISCHYRA Loeblich and Tappan, n. sp.
Plate 14, figures 20a–b

Test free, large, flattened, early portion coiled, later uncoiling, peripheral margin slightly curved; chambers increasing gradually in size from the rounded proloculum, 10 in the holotype; sutures distinct, thickened and slightly raised, highest at the periphery, curving downwards at the ventral margin; wall calcareous, finely perforate, surface smooth; aperture radiate, at the peripheral angle.

Length of holotype 1.17 mm., greatest breadth 0.39 mm., greatest thickness 0.18 mm.; other specimens up to 1.22 mm. in length.

Types and occurrence.—Holotype (USNM 105031) from Sample J-50 d; unfigured paratype (USNM 105032) from Sample J-50 c.

Remarks.—*Vaginulina ischyra*, n. sp., differs from *Cristellaria* (*Cristellaria*) *humilis* Reuss in being more than twice as large, and in having more oblique sutures. It is distinguished from *Cristellaria hybrida* Terquem in having a less well-developed coil, in the presence of raised limbate sutures, and in lacking the costae present in *C. hybrida*.

VAGINULINA LECHRIOSA Loeblich and Tappan, n. sp.
Plate 14, figures 21a–b

Test free, flattened, subtriangular in outline; chambers increasing gradually in breadth as added, with very little increase in height, nine present in the holotype; sutures distinct, depressed, strongly oblique; wall calcareous, finely perforate, surface smooth; aperture radiate, at the peripheral angle.

Length of holotype 0.44 mm., greatest breadth 0.13 mm., greatest thickness 0.07 mm. Other specimens are from 0.34 mm. to 0.52 mm. in length.

Types and occurrence.—Holotype (USNM 105037) and unfigured paratypes (USNM 105038) from Sample J-50 d.

Remarks.—*Vaginulina lechriosa*, n. sp.,

EXPLANATION OF PLATE 15

FIGS. *1–12*—*Citharina entypomatus* Loeblich and Tappan, n. sp. *1*, Megalospheric paratype (USNM 105046a) showing wide form with regular increase in breadth; *2*, microspheric paratype (USNM 105046b) showing small proloculum and slow early increase in breadth, followed by later more regular increase in breadth, so that test has a sinuate ventral margin; *3*, paratype (USNM 105045a) showing smaller form with development similar to paratype of figure *2*; *4*, paratype (USNM 105046c), a small microspheric form with tapering initial portion; *5*, megalospheric paratype (USNM 105044), showing straight dorsal margin and regularly curved ventral margin; 6, microspheric paratype (USNM 105046d) showing very small form; *7*, megalospheric paratype (USNM 105046e); *8a*, side view of holotype (USNM 105042), showing large microspheric form, gently arched sutures and numerous fine costae; *8b*, ventral view, showing subacute margin and gradual early increase in thickness; *9*, paratype (USNM 105046f); *10*, paratype (USNM 105043) showing narrower specimen; *11*, paratype (USNM 105046g) showing small narrow form; *12*, paratype (USNM 105045b) showing narrow form with later chambers of less breadth than those preceding; all ×41. (p. 57)

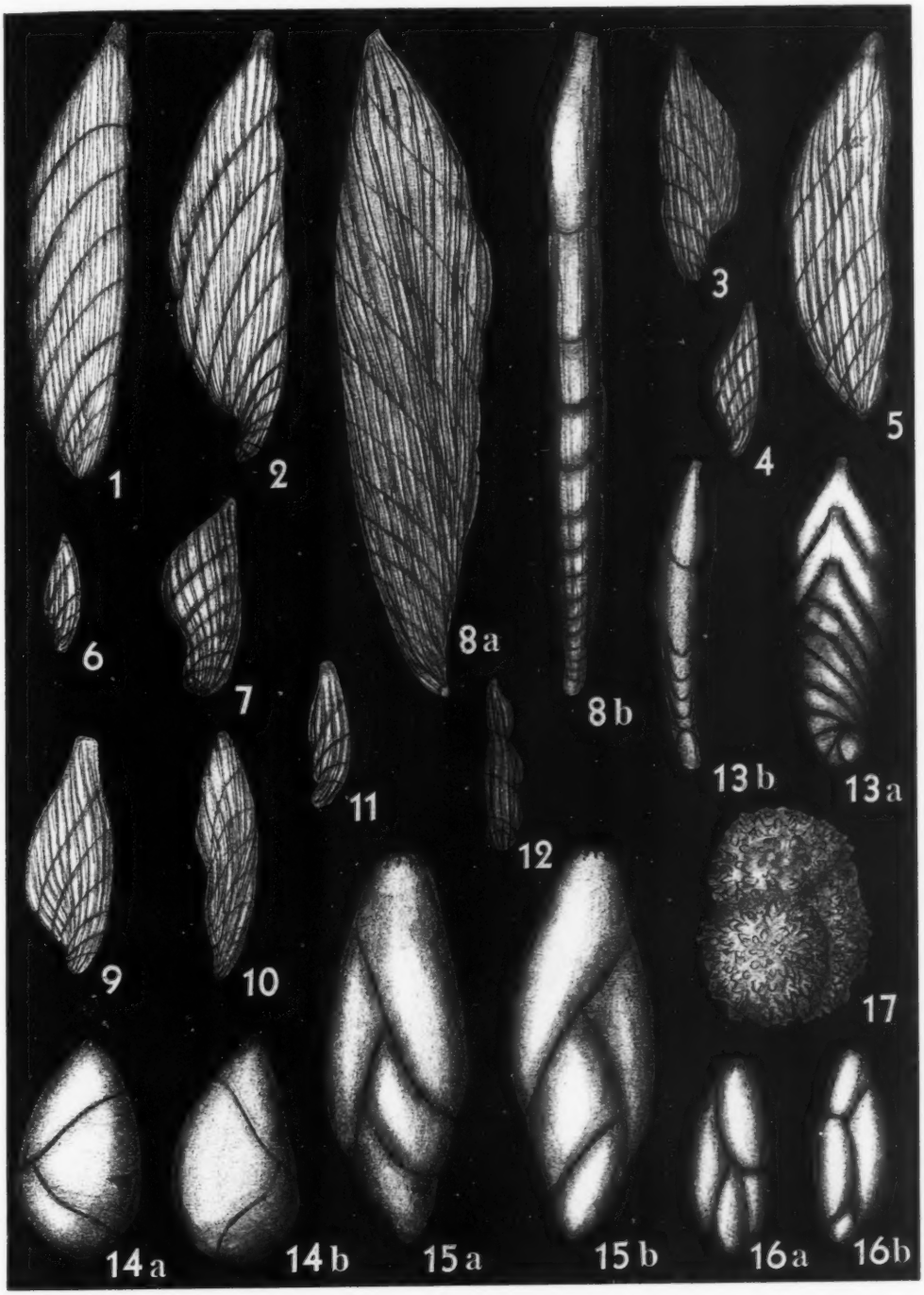
13a–b—*Falsopalmula antrorsa* Loeblich and Tappan, n. sp. *13a*, side view of holotype (USNM 105051), showing evolute coil, followed by vaginuline chambers and final equitant chambers; *13b*, edge view; ×72. (p. 57)

14a–b—*Guttulina physalia* Loeblich and Tappan, n. sp. *14a*, side view of holotype (USNM 105062), showing rounded base and chamber arrangement; *14b*, opposite side; ×95. (p. 59)

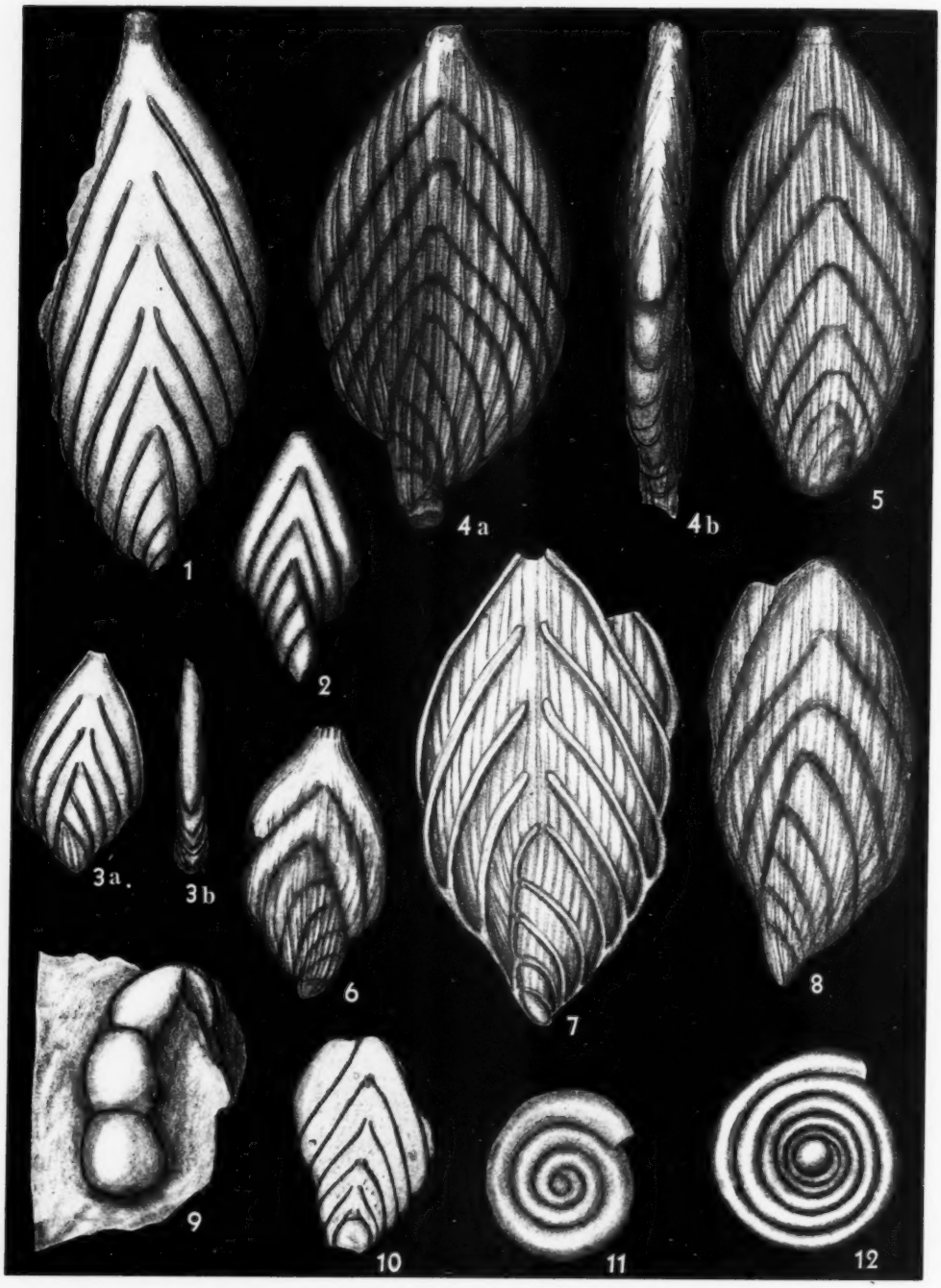
15a–b—*Paleopolymorphina elacatoides* Loeblich and Tappan, n. sp. *15a*, side view of holotype (USNM 105061), showing fusiform test and early spiral chambers followed by biserial ones; *15b*, opposite side; ×95. (p. 59)

16a–b—*Eoguttulina amygdalina* Loeblich and Tappan, n. sp. *16a*, side view of holotype (USNM 105060), showing almond-shaped test, elongate chambers and depressed sutures; *16b*, opposite side; ×95. (p. 59)

17—*Ramulinella ecphyma* Loeblich and Tappan, n. sp. Holotype (USNM 105063) showing three-chambered, hispid test with depressed sutures; ×72. (p. 59)



Loeblich and Tappan, Jurassic Foraminifera



Loeblich and Tappan, Jurassic Foraminifera

differs from *V. biplicata* Terquem in being less than one-fourth as large, and in having more oblique sutures. It differs from *Dentalina bicornis* Terquem in having a less arcuate test, in being about one-half as large and in having more oblique sutures. The present species has a straighter dorsal margin and more oblique sutures than *Dentalina oolithica* Terquem and is approximately one-half the size of that species.

Genus CITHARINA d'Orbigny, 1839
CITHARINA ENTYPOMATUS Loeblich and Tappan, n. sp.
Plate 15, figures 1–12

Test free, large, flattened, subtriangular in outline, peripheral margin varies from straight to slightly convex; chambers increasing gradually in breadth as added, but increasing very little in height, so that the later chambers are very broad and low, as many as 16 chambers in well-developed specimens; sutures slightly depressed, distinct when specimen is dampened, but otherwise may be obscured in some specimens by the fine longitudinal costae which cross the sutures, sutures oblique, highest at the peripheral margin, very slightly curved, convex toward the aperture; wall calcareous, finely perforate, surface ornamented with numerous low, fine, longitudinal ribs, from 5 to 15 crossing a single chamber, ribs about equidistant, increasing in number as the test broadens; aperture radiate, at the end of a slight neck at the peripheral angle.

Length of holotype 2.29 mm., greatest breadth 0.55 mm., greatest thickness 0.21 mm. Other specimens are from 0.42 mm. to 2.29 mm. in length.

Types and occurrence.—Holotype (USNM 105042) and figured paratype (USNM 105043) from Sample J-50 e; figured paratype (USNM 105044) from Sample J-50 a; figured paratypes (USNM 105045 a–b) from Sample J-50 b; figured paratypes (USNM 105046 a–g) and unfigured paratypes (USNM 105048) from Sample J-50 d.

Remarks.—*Citharina entypomatus*, n. sp., differs from *Marginulina flabelloides* Terquem in being less flabellate, in having a more curved dorsal margin and in possessing many more ribs. It is slightly larger than *Marginulina condita* Terquem and has less depressed sutures. It has a less triangular test than *Marginulina tumida* Terquem and lacks the tumid lower portion of that species.

Genus FALSOPALMULA Bartenstein, 1948
FALSOPALMULA ANTRORSA Loeblich and Tappan, n. sp.
Plate 15, figures 13a–b

Test free, elongate, palmate, flattened, early portion coiled, later portion uncoiled

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EXPLANATION OF PLATE 16

FIGS. *1–3b*—*Citharinella rhomboidea* Loeblich and Tappan, n. sp. *1*, side view of paratype (USNM 105050a), showing rhombic test, early *Citharina*-like chambers, followed by chevron-shaped chambers, and thickened sutures; *2*, small paratype (USNM 105050b); *3a*, side view of holotype (USNM 105049), showing costae on the proloculum, and overlap of the *Citharina* stage by the equitant chambers; *3b*, edge view, showing greatest thickness through the proloculum; all ×48. (p. 58)

4–8—*Citharinella exarata* Loeblich and Tappan, n. sp. *4a*, side view of holotype (USNM 105054), showing early *Citharina* stage followed by very broad chevron-shaped chambers, with thickened sutures and numerous costae ornamenting the surface; *4b*, edge view of holotype; *5*, side view of paratype (USNM 105052a), showing equitant chambers embracing the early short *Citharina* stage; *6*, small paratype (USNM 105053) showing costae stronger on the citharine stage than on the equitant chambers; *7*, paratype (USNM 105055) showing very thick sutures; *8*, paratype (USNM 105052b) showing slightly depressed sutures and numerous fine costae; all ×48. (p. 58)

9—*Vitriwebbina* sp. Top view of specimen (USNM 105064), showing globular chambers of test encrusting a shell fragment; ×22. (p. 60)

10—*Frondicularia* sp. Side view of specimen (USNM 105058), showing diamond-shaped test, and bulbous proloculum followed by acutely angled equitant chambers; ×48. (p. 58)

11—*Spirillina amphelicta* Loeblich and Tappan, n. sp. Side view of holotype (USNM 105065), showing globular proloculum followed by undivided spiral, tubular second chamber; ×146. (p. 60)

12—*Spirillina* sp. Side view of limonitic cast (USNM 105067), showing large proloculum followed by close coiled, undivided tubular second chamber; ×106. (p. 60)

and vaginuline, final chambers becoming equitant; chambers numerous, four to five in the coil, followed by about four uncoiled vaginuline chambers and two chevron-shaped chambers, chambers low and broad, increasing very little in height as added; sutures distinct, depressed; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate, at the end of a short neck.

Length of holotype 0.63 mm., greatest breadth 0.18 mm., greatest thickness 0.05 mm.

Types and occurrence.—Holotype (USNM 105051) from Sample J-50 b.

Remarks.—*Falsopalmula antrorsa*, n. sp., differs from *Flabellina centralis* Terquem in having a tighter coil. It is about one-third smaller than *Flabellina centro-gyrata* Terquem, has more oblique sutures and a less well-developed coil. *Flabellina obliqua* Terquem is somewhat similar, but has a more enrolled early stage, less oblique sutures, and less regular equitant chambers.

Genus CITHARINELLA Marie, 1938
CITHARINELLA EXARATA Loeblich and Tappan, n. sp.
Plate 16, figures 4–8

Test free, large, palmate, flattened, early portion citharine, later portion composed of very broad chevron-shaped chambers, periphery truncate; chambers numerous, increasing gradually in breadth as added, but increasing very little in height or thickness, so that the mature test is wide and flat, five to six citharine chambers followed by as many as six equitant chambers; sutures distinct, thickened, occasionally slightly depressed; wall calcareous, finely perforate, surface ornamented by from 15 to 20 fine longitudinal costae; aperture terminal, radiate, on a short neck.

Length of holotype 1.48 mm., greatest breadth 0.78 mm., greatest thickness 0.13 mm. Other specimens are from 0.81 mm. to 1.48 mm. in length.

Types and occurrence.—Holotype (USNM 105054) from Sample J-50 d; figured paratype (USNM 105055) from Sample J-50 a; unfigured paratype (USNM 105056) from Sample J-50 f; figured paratypes (USNM 105052 a–b) from Sample J-50 g; figured paratype (USNM 105053) and unfigured paratype (USNM 105057) from Sample J-50 i.

Remarks.—*Citharinella exarata*, n. sp., differs from *Flabellina karreri* Berthelin in lacking the acuminate initial portion, in possessing more thickened sutures and in having less embracing chambers. It is distinguished from *Frondicularia pinnaeformis* Chapman by its broader test, in lacking the acuminate initial portion and in possessing the surface ornamentation of fine costae across the chambers as well as at the sutures.

CITHARINELLA RHOMBOIDEA Loeblich and Tappan, n. sp.
Plate 16, figures 1–3b

Test free, large, palmate, flattened, early portion as in *Citharina*, later chambers equitant; chambers numerous, broad and low, increasing rapidly in breadth as added, from three to four *Citharina*-like chambers following by three to six chevron-shaped chambers; sutures distinct, depressed, acutely arched upward centrally in the later portion of the test; wall calcareous, finely perforate, surface smooth; aperture radiate, terminal, on a slight neck.

Length of holotype 0.68 mm., greatest breadth 0.39 mm., greatest thickness 0.05 mm. Other specimens are from 0.68 mm. to 1.69 mm. in length.

Types and occurence.—Holotype (USNM 105049) and figured paratypes (USNM 105050 a–b) from Sample J-50 a.

Remarks.—*Citharinella rhomboidea*, n. sp., differs from *Frondicularia watersi* Cushman in having less embracing early chambers and in lacking the ornamentation on the outer ends of the sutures. It is distinguished from *Frondicularia pinnaeformis* Chapman in lacking any surface ornamentation and in having a broader test. It differs from *Flabellina karreri* Berthelin in lacking the acuminate initial portion and in possessing an unornamented test. *Citharinella rhomboidea*, n. sp., is similar to *Flabellina jurensis* Franke, but attains a somewhat greater size, is broader and more rhomboidal in outline and possesses thickened sutures.

Genus FRONDICULARIA Defrance, 1824
FRONDICULARIA sp.
Plate 16, figure 10

Test free, broad, palmate, flattened; proloculum round and inflated, followed by

compressed chevron-shaped chambers which are acutely angled so that the test is diamond-shaped; sutures distinct, thickened and slightly elevated; wall calcareous, finely perforate, surface smooth; aperture radiate, terminal.

Length of figured specimen 0.65 mm., greatest breadth 0.42 mm., greatest thickness 0.10 mm.

Types and occurrence.—Figured specimen (USNM 105058) from Sample J-50 a.

Remarks.—The specimen figured is the only representative of this genus yet found at this locality, and as it is somewhat fragmentary no specific determination has been made.

Family POLYMORPHINIDAE
Genus EOGUTTULINA Cushman and Ozawa, 1930
EOGUTTULINA AMYGDALINA Loeblich and Tappan, n. sp.
Plate 15, figures 16a–b

Test free, small, acuminate; chambers narrow and elongate, added in a spiral series, each chamber farther removed from the base; sutures distinct, depressed; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Length of holotype 0.31 mm., greatest breadth 0.13 mm., greatest thickness 0.09 mm.; other specimens from 0.21 mm. to 0.36 mm. in length.

Types and occurrence.—Holotype (USNM 105059) and unfigured paratypes (USNM 105060) from Sample J-50 h.

Remarks.—*Eoguttulina amygdalina*, n. sp., is similar to *Eoguttulina liassica* (Strickland) but is slightly more pyriform in outline and the chambers are not as elongate.

Genus PALEOPOLYMORPHINA Cushman and Ozawa, 1930
PALEOPOLYMORPHINA ELACATOIDES Loeblich and Tappan, n. sp.
Plate 15, figures 15a–b

Test free, large, acuminate, early portion spiral, later biserial; chambers elongate and narrow, each chamber farther removed from the base; sutures distinct, slightly depressed; wall calcareous, finely perforate, surface smooth; aperture radiate, terminal.

Length of holotype 0.60 mm., greatest breadth 0.21 mm., greatest thickness 0.18 mm. Other specimens are from 0.52 mm. to 0.60 mm. in length.

Types and occurrence.—Holotype (USNM 105061) from Sample J-50 c.

Remarks.—*Paleopolymorphina elacatoides*, n. sp., is similar in appearance to *Paleopolymorphina gaultina* (Berthelin), but is about three times as large and is comparatively somewhat more slender and tapering.

Genus GUTTULINA d'Orbigny, 1839
GUTTULINA PHYSALIA Loeblich and Tappan, n. sp.
Plate 15, figures 14a–b

Test free, small, pyriform; chambers arranged in a quinqueloculine series, each succeeding chamber farther removed from the base; sutures distinct, slightly depressed; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Length of holotype 0.36 mm., greatest breadth 0.21 mm., greatest thickness 0.18 mm. Other specimens are from 0.26 mm. to 0.36 mm. in length.

Types and occurrence.—Holotype (USNM 105062) from Sample J-50 h.

Remarks.—*Guttulina physalia*, n. sp., is similar in general size and appearance to *Guttulina caudata* d'Orbigny, but differs in being more slender and in having a rounded base rather than the pointed base of *G. caudata*.

Genus RAMULINELLA Paalzow, 1932
RAMULINELLA ECPHYMA Loeblich and Tappan, n. sp.
Plate 15, figure 17

Test free, composed of subglobular chambers in an irregular arrangement, only three chambers present in the holotype; sutures distinct, depressed; wall calcareous, finely perforate, surface covered with numerous fine spines; aperture not observed.

Greatest diameter of holotype 0.49 mm., least diameter 0.36 mm., thickness 0.29 mm.

Types and occurrence.—Holotype (USNM 105063) from Sample J-50 d.

Remarks.—*Ramulinella ecphyma*, n. sp., differs from *R. suevica* Paalzow in having a more compacted test instead of being irregularly rectilinear, and in lacking the apertural extension on the final chamber.

Genus VITRIWEBBINA Chapman, 1892
VITRIWEBBINA sp.
Plate 16, figure 9

Test attached, consisting of a series of hemispherical chambers, increasing gradually in size as added; sutures distinct; wall calcareous, finely perforate, surface smooth; aperture a low arch adjacent to the attachment.

Length of figured specimen 1.98 mm., length of single chamber 0.55 mm.

Types and occurrence.—Figured specimen (USNM 105064) from Sample J-50 a.

Remarks.—This genus is represented in our Redwater material solely by the figured specimen, hence no specific determination has been made.

Family SPIRILLINIDAE
Genus SPIRILLINA Ehrenberg, 1843
SPIRILLINA AMPHELICTA Loeblich and Tappan, n. sp.
Plate 16, figure 11

Test free, minute, planispiral, much compressed, consisting of a globular proloculum followed by an undivided tubular spiral second chamber which makes about four complete coils; spiral suture distinct; wall calcareous, finely perforate, surface smooth; aperture formed by the open end of the tube.

Greatest diameter of holotype 0.17 mm., least diameter 0.14 mm., thickness 0.03 mm.; other specimens from 0.10 mm. to 0.17 mm. in diameter.

Types and occurrence.—Holotype (USNM 105065) and unfigured paratypes (USNM 105066) from Sample J-50 b.

Remarks.—*Spirillina amphelicta*, n. sp., is similar to *S. orbicula* Terquem and Berthelin, but is approximately one-third smaller in size. It is about one-seventh the size of *S. regularis* Terquem, and about one-half as large as *Spirillina tenuissima* Gümbel.

SPIRILLINA sp.
Plate 16, figure 12

Test free, small, planispiral, consisting of a globular proloculum, followed by a long, undivided, close-coiled tubular second chamber, with five complete whorls present in the figured specimen; wall calcareous, perforate, but in the Redwater material specimens are represented only by internal casts; aperture formed by the open end of the tube.

Greatest diameter of figured specimen 0.29 mm., least diameter 0.23 mm., greatest thickness 0.07 mm.

Types and occurrence.—Figured specimen (USNM 105067) from Sample J-50 f.

Remarks.—This species is about one and one-half times as large as *Spirillina amphelicta*, n. sp., has a more globular proloculum and more regularly enlarging second chamber. It is represented only by limonitic internal casts, however, and hence is not specifically identified.

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JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 1, PP. 61–62, PL. 17, JANUARY 1950

A PERMIAN ALGAL-FORAMINIFERAL CONSORTIUM FROM WEST TEXAS

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THE U. S. National Museum field parties in the course of their studies of the Permian of west Texas discovered a large deposit of "algal balls" near Vinton, Texas. These were sent to the writer for study by G. Arthur Cooper.

Thin sections of these balls show them to be composed of an intimate intergrowth of Foraminifera and algae similar to those previously reported by the author from the Pennsylvanian of New Mexico (Johnson, 1938) and from the Pennsylvanian and Lower Permian of Kansas (Johnson, 1947). The masses are larger and more spherical than any previously studied by the writer.

GENERAL DESCRIPTION

The fossils form spherical to egg-shaped calcareous masses 5.5 to 8.2 cm. long and 4.8 to 6.2 cm. wide. The surface is covered by irregular rounded protuberances (pl. 17, fig. 1).

In thin section they consist of irregular masses of tubular organisms in a groundmass of clear calcite. A close examination of the organisms shows the presence of two quite different kinds of tubes, one algal (*Girvanella*) and one foraminiferal (*Nubecularia*). They are intimately entwined.

Genus NUBECULARIA Defrance, 1825
NUBECULARIA PERMIANA Johnson, n. sp.
Plate 17, figures 3, 4

Description.—Encrusting tubular. Tubes usually semi-circular, sometimes flattened or irregular. Bottom of tube flattened, but conforming to substratum. Tubes have walls of fibrous calcite, usually thick on top and thinner at base. Tubes vary considerably in size, ranging from 0.135 to 0.500 mm. wide and 0.09 to 0.350 mm. high. Walls from 0.01 to 0.027 mm. thick.USNM 40513a–c.

Genus GIRVANELLA Nicholson and Etheridge, 1880
GIRVANELLA TEXANA Johnson, n. sp.
Plate 17, figures 1, 2

Description.—Sinuous tubes nearly circular in section, having a diameter ranging from 0.046 to 0.057 mm., averaging 0.055 mm. They have well-defined walls of very fine calcite particles (algal dust) which appear almost black. Walls 0.008 mm. thick. USNM 40513a–c.

Remarks.—This species is remarkable for the large size of the tubes. They are slightly larger than *Girvanella magma* Johnson from the Middle Pennsylvanian of Kansas. In habit and appearance they greatly resemble the *Girvanella* mentioned but not named by Wood (1948, p. 15), but the tubes are considerably larger.

Perforating algae.— In some areas of the specimens the *Girvanella* have been filled with very fine branching algal threads which have pierced and often largely destroyed the walls of the tubes. In only a few cases has the same happened to the *Nubecularia*.

Conclusion.—These fossils represent an intimate intergrowth of algae and Foraminifera apparently in a symbiotic relationship. Associated with them are fine threads of a perforating alga, possibly parasitic.

In a previous study of a similar consortium from the Pennsylvanian and Permian of Kansas (Johnson, 1947) the evidence suggested that while the association was probably symbiotic, in the end it was destructive to the foraminiferal tests. However the present material presents a different picture. There is no appearance of the *Girvanella* penetrating or destroying the *Nubecularia*. Locally there are areas in which tiny threadlike algae have penetrated and filled the *Girvanella* tubes with some de-

struction of the walls. The *Nubecularia* tubes are only very rarely attacked.

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MANUSCRIPT RECEIVED MAY 24, 1949.

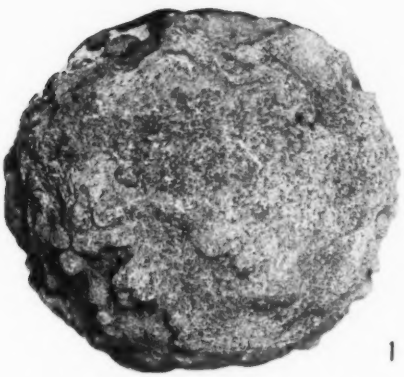
EXPLANATION OF PLATE 17

Permian Algal-Foraminiferal Consortium

FIG. *1*—The algal-foraminiferal nodules (×1) (upper) sawed and etched, USNM 40513a, (lower) the weathered nodule, USNM 40513b.

2—*Girvanella texana* Johnson, n. sp. (×75) a thick mass of black tubes crossing center of the area—the white tubes are Foraminifera, USNM 40513a.

3, 4—Coarse tubes of *Nubecularia permiana* Johnson, n. sp. penetrated and partly filled with fine (black) threads of perforating algae. *Girvanella* tubes (black) between and around the larger foraminiferal tubes (×75), USNM 40513a.



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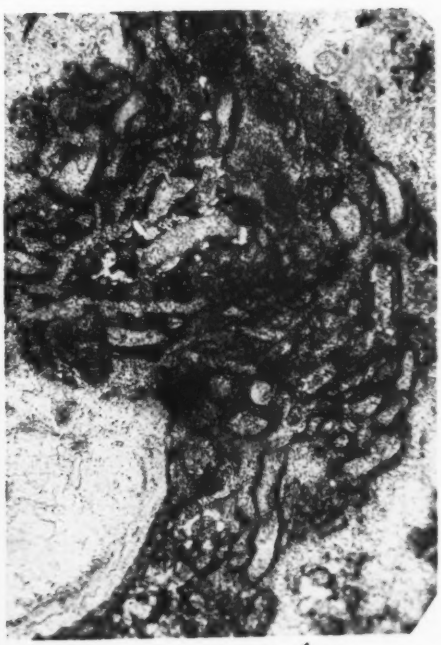

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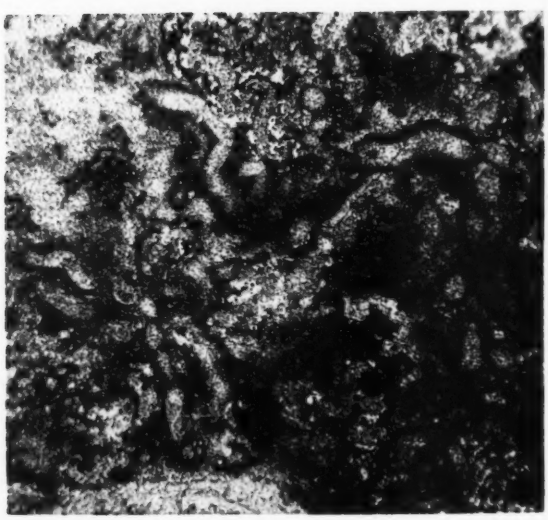

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Johnson, Permian algal consortium

JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 1, PP. 63–75, 16 TEXT FIGS., JANUARY 1950

THE HINGEMENT OF PALEOZOIC OSTRACODA AND ITS BEARING ON ORIENTATION

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ABSTRACT—The hingements of species of fifteen Paleozoic ostracode genera are described. The importance of hingement in the classification, identification and evolutionary history of ostracodes is stressed and it is shown that hingement can be used as a criterion for orienting Paleozoic ostracodes.

INTRODUCTION

THIS study describes the hitherto unknown hingement of a number of species of early Paleozoic ostracodes. Definite hinge components were observed on species of the following genera: *Beyrichia*, "*Primitia*," *Milleratia*, *Primitiopsis*, *Eridoconcha*, *Ceratopsis*, *Ulrichia*, *Hollina*, *Bromidella*, *Ctenobolbina*, *Thlipsura*, *Thlipsurella*, *Rothella*, *Eucraterellina* and *Phanassymetria*.

It has been assumed that early Paleozoic ostracode genera were devoid of any means of articulation or that the hingement was "simple," consisting of only a groove in one valve with an extension of the dorsal margin of the opposite valve fitting into the groove. However these studies show that many early genera exhibit a method of hingement which is much more complex. Furthermore the writer has observed that within the ostracodes the groove, although commonly in the left valve, does not consistently appear in this valve as Bonnema (1930) believes from his observations of a limited number of genera.

From the beginning of this work it was evident that there was a lack of conformity among various workers in the orientation of species obviously of the same genus or of related genera. For this reason the usual orientation in some instances has been reversed. In other cases the anterior end has been chosen to agree with the hinge development and other criteria of living forms.

There appears to be enough variation in hingement within the early Paleozoic ostracodes so that this feature may be used in identification and classification. To cite an example: the genera *Hollinella* and *Hollina* are difficult to differentiate and a single reliable characteristic for distinguishing between them has been lacking. Hingement of the observed *Hollina* is radically different from the hingement of *Hollinella* described by Kellett (1929), and may be used as a basis for differentiating these genera.

The classification here used is that proposed by Swartz (1936), except that in this paper *Eridoconcha* is placed in the family Primitiidae instead of the family Aparchitidae.

ACKNOWLEDGEMENTS

The author is indebted to Mrs. Betty Kellett Nadeau for her suggestion of the problem and for her encouragement and advice. Dr. E. Triebel of Frankfurt-am-Main, Germany made available a number of foreign publications pertinent to this paper and kindly offered helpful comments.

SELECTION OF MATERIAL

Specimens were selected from as near the horizon and locality of the holotype as was possible; however, in some instances specimens closely related to the holotype or to type species did not yield well preserved single valves showing the hinge components. Such valves are not common in the early Paleozoic; in many cases fifty to one hundred fairly well preserved specimens were examined with only one valve showing the hinge components. Valves in which the hingeline is still covered by the rock matrix often exhibit hingement when placed under the microscope and the matrix is then picked away with a very fine needle. Although tedious, this work may yield excellent results.

DETERMINATION OF HINGEMENT

To determine the method of articulation, the valve is turned in many positions under varying magnifications, starting with a low magnification of 35× and progressing to a high of 120×, which is as high a magnification as can be of value. All drawings were made with the camera lucida mounted on a monocular microscope with the reflecting mirror placed at an angle of 45° to yield the least possible distortion. The drawings were then put in an opaque projector and enlarged on a screen to nine by fifteen inches, after which they were traced, inked, photostated and reduced to the size shown here. It was not feasible to enlarge all specimens to the same degree to show the relative size of the valves; if this had been done, the hingement on some of the smaller forms would have been indistinguishable on the drawings. The magnification and the original size of the valve in millimeters are given under each figure. All shell measurements were made by means of the ocular micrometer on the binocular microscope.

On many specimens all of the components of the hinge are not visible in one position of the valve; because of this, some of the drawings are composite views of a valve in slightly different positions so that all of the hingement appears in one drawing. Photographs although preferable to drawings were not used, primarily for this reason. The hingement of the early Paleozoic genera is not as pronounced and easily observed as that of the Mesozoic and Tertiary forms. Because of their relative simplicity there is always the danger of mistaking differential weathering of the shell for hingement. When any doubt arose as to the hinge components many molts of the same species were examined, and only if the hingement was the same and in the same relative position were the observations accepted as valid. Hingements of the specimens described are generally typical of the species and genus, although it was noted that within some species there are minor variations in the hinge components.

This paper is only preparatory to the larger task of describing the still unknown hingement of species of many genera, and of ascertaining the true variation in hingement from the first appearance of a genus to its final disappearance.

ORIENTATION

In the description of the hingement it became necessary to determine the orientation of the valves. Examination of the literature on Paleozoic genera reveals a great deal of uncertainty relative to their orientation, that is, as to the determination of the anterior end of the valve. (Geis, 1932; Kay, 1934, 1940; Swartz, 1933, 1936; Swartz and Oriel, 1948; Warthin, 1933 and many others.) Although most of the workers on Paleozoic ostracodes are undecided they still employ either the criteria for orientation set forth by Ulrich and Bassler or they utilize the different criteria of Bonnema which often result in an opposite orientation. Students of the post-Paleozoic ostracodes approach the problem using still other criteria which they employ in working with the post-Paleozoic forms, so that altogether the situation as it now stands is not satisfactory.

Through a study of the hingement of Mesozoic and Tertiary genera the writer believes that additional criteria can be established that may aid in the orientation of the carapaces of the Paleozoic genera. In all post-Paleozoic genera that can be associated with living forms, it was found that the hingement is more highly developed at the anterior.[1] This idea is not new, it was suggested by Bonnema (1932), but never developed.

In many of the ostracode genera the hingement does not remain stable, but slowly evolves from one type to another along definite lines. It was found that the change in hingement at the anterior portion of the valve points to the development that the posterior portion will later attain. In *Cythereis* and related post-Paleozoic genera there is a gradual evolution of the anterior hinge component from the Jurassic into the Tertiary with a change from a crenulate, flange-like tooth or toothlets and corresponding sockets to a more tooth-like projection with a reduction in the number of toothlets or crenulations, and culminating in a knob-like tooth and secondary post-adjacent socket (see also Trie-

[1] Exceptions: *Paracytheridea* and *Metacypris*, the latter noted by Kellett and by Triebel; and species of *Conchoecia* by Triebel (Personal Communication).

bel, 1940 and Bradley, 1948). Other ostracode genera when they first appear in the Mesozoic and Tertiary are in various stages of hinge evolution and many evolve from these stages to more specialized forms. This evolution in hingement is seen not only within the life of a genus, but commonly appears also within the life of an individual. No doubt there is more than one line of hinge evolution; but the writer believes that the main line of evolution follows a pattern similar to that outlined below:

1. A simple groove in one valve and a ridge in the other.
2. The anterior portion of the groove developing either a tooth, toothlets or a socket, and the anterior portion of the ridge developing a corresponding socket, toothlets or a tooth.
3. The posterior portion of the groove and ridge attaining the development of the anterior portion.
4. Secondary hinge components developing on the anterior portion of the valve.

(Note: Crenulations on the hinge components may occur after 1, 2, or 3 above.)

The anterior end of post-Paleozoic ostracodes can also be distinguished by the tendency of the anterior hinge component to be more rounded than the posterior and for the posterior component to be more oblique to the dorsal margin.

Although the early Paleozoic genera do not exhibit the wide range of hinge development shown in post-Paleozoic genera, often they do show a higher development of the hinge components at one portion of the valve, and if teeth and sockets are present one tooth is usually more oblique to the dorsal margin than the other. In Paleozoic genera which exhibit dimorphism and in which orientation is consequently known, the hingement is consistent with the criteria set forth above. (The recent work of Hessland [1949] and Triebel [1941] offer possible interpretations of "brood pouches.") Furthermore, orientation of Paleozoic ostracodes based on hingement is identical with that based on the criteria used by post-Paleozoic workers (Bold, Triebel, etc.). Admittedly it is not always possible to determine the orientation of Paleozoic ostracodes by hingement alone, and it should be used in conjunction with other criteria. Only continued work will definitely establish its value in orientation.

It will be found in many living short-hinged ostracodes that when the shell is opened the gap is slightly greater at the anterior. In fossil short or "curved" hinged forms this can be satisfied by considering the plenate end as the anterior, which consequently gives a somewhat "posterior" position to the hingeline. In forms like the thlipsurids where the hinge is short and not parallel to the ventral margin, the plenate end would be the anterior. This anterior position of the plenate end in the thlipsurids is established by its accepted relationship to the cyprids and bairdias.

The criteria used in this paper for determining the orientation include:

1. Hingement. The higher development of the anterior hinge component, and the relative shape and position of the hinge components.
2. Major spines. As shown by Triebel, Bold and others, the major spines point to the posterior.
3. Dimorphism. When dimorphism can be shown the posterior of the female is thicker.
4. Development. If a series of molts are available from youth to adult, in lateral view the posterior will "fill out" with maturity. (Kellett, oral communication)
5. Sulcus and muscle scar. The main sulcus and muscle scar will be anterior to the center of the valve. (Hessland, 1949 and Triebel, 1941.)

For the description of the specimens it was sometimes necessary to describe the valves so that the reader could ascertain which valve was being discussed. In doing so "plenate" and "antiplenate" and "right- and left-plenate" were used as put forth by Swartz (1945) and Swartz and Oriel (1948).

CONCLUSIONS

There is no doubt that simple to fairly complex hingement occurs in the early Paleozoic ostracode genera, and that this hingement varies among genera so that it may be employed in classification, identification and orientation. The resultant orientation is consistent with other criteria, but the dependability of its use in orienting

Paleozoic ostracodes can be definitely established only if continued work is directed along this line. As Alexander has stated (1934), the only way in which the micropaleontologist can hope to achieve a correct classification for the fossil ostracode is to make a careful study of all of the shell structures of the various genera, taking into consideration more features and studying them in greater detail than in the past.

DESCRIPTION OF HINGEMENT OF SPECIES

Order OSTRACODA Latreille, 1802

Superfamily BEYRICHIACEAE Ulrich and Bassler, 1923

Family BEYRICHIIDAE Jones, 1894

Genus BEYRICHIA M'Coy, 1846

BEYRICHIA FITTSI Roth, 1929

Beyrichia fittsi ROTH, 1929. Jour. Paleontology, vol. 3, no. 4, p. 340, pl. 35, figs. 6a–d.

Hingement.—The hingement of the right valve of *Beyrichia fittsi* Roth consists of a groove running the entire length of the dorsal margin; it is slightly restricted at the anterocentral portion of the valve and is slightly expanded near the anterocardinal angle. The hingement of the left valve consists of a fine ridge running the entire length of the dorsal margin.

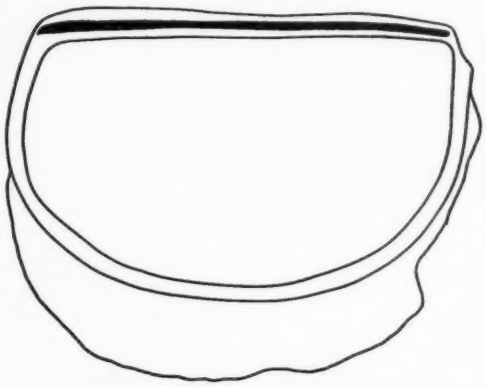


FIG. 1—*Beyrichia fittsi* Roth, right valve, showing a groove along the length of the dorsal margin. Length, 1.75 mm.; height, 0.94 mm. ×37.

Remarks.—The type species of *Beyrichia* is *B. kloedeni* M'Coy from the Llandovery (Lower Silurian) of Ireland. The specimens of *B. fittsi* examined are topotypes from the Haragan (Lower Devonian) of the famous White Mound locality, three miles southeast of Dougherty, Oklahoma. Although differing some from the genotype, *B. fittsi* seems to be a typical *Beyrichia*.

The orientation here used is opposite from that which was formerly accepted for *Beyrichia* and differs from that used by Roth in his original description of the species. The specimens have been reversed because of the development of the hinge at the anterior portion of the valve. A number of specimens of *B. tuberculata* (Klöeden) and *B. waldronensis* Ulrich and Bassler from the Silurian were also examined and the hingement of these correspond to that of *B. fittsi*. Triebel's orientation (1941, pl. 9, figs. 103a, b; pl. 11, figs. 131–132) agrees with that of the author.

Roth in his original description of the species found no dentition or apparent method of articulation. The writer found one right valve and one left valve of *B. fittsi* with well preserved hingement.

Figured specimen is Washington University No. 700011.

Genus BROMIDELLA Harris, 1931

BROMIDELLA RETICULATA Harris, 1931

Bromidella reticulata HARRIS, 1931. Oklahoma Geol. Surv., Bull. 55, p. 93, pl. 14, figs. 6a, b.

Hingement.—The hingement of the right valve of *Bromidella reticulata* Harris consists of elongate cardinal sockets which taper to the center of the valve with a ridge between them. The posterior socket is not as elongate as the anterior and may be restricted to the postcardinal angle. This variation in the length may be individual variation or it may be due to the poor pres-

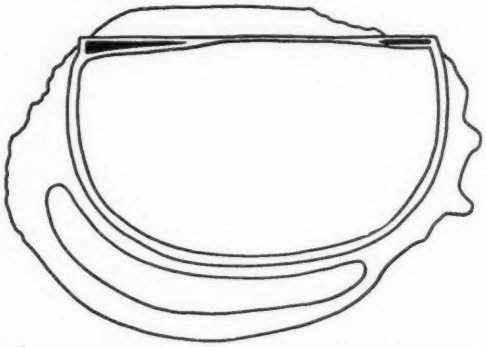


FIG. 2—*Bromidella reticulata* Harris, right valve, female, showing elongate anterior and posterior sockets and well-defined connecting ridge. Length, 1.38 mm.; height, 0.99 mm. ×51.

ervation of some specimens. No left valves were found in which hingement was discernible.

Remarks.—The type species of *Bromidella* is *B. reticulata* from the Bromide (Middle Ordovician) of the Arbuckle Mountains of Oklahoma. The specimens examined are from this horizon and from a near locale, Fitts Pool, Oklahoma. They were in the collection of the late William Warner.

The orientation here used is opposite to that of Harris (1931, p. 93), but it agrees with Triebel's orientation (1941, p. 11, fig. 133). The orientation is reversed because of the presence of major spines pointing to the antiplenate end of the valve on the holotype and the specimens examined; in addition, the hingement is more advanced on the plenate end.

Ten right valves were found with well preserved hingement. The components of hinge of the left valve were in all cases obscured by poor preservation.

Figured specimen is Washington University no. 700002.

Family PRIMITIIDAE Ulrich and Bassler, 1923

Genus PRIMITIA Jones and Holl, 1865

"PRIMITIA" BONNEMAI Swartz, 1936

"*Primitia*" *bonnemai* SWARTZ, 1936. Jour. Paleontology, vol. 10, no. 7, pp. 566–567, pl. 86, figs. 6a–g.

Hingement.—The hingement of the left valve of "*Primitia*" *bonnemai* Swartz consists of a fine, distinct, low ridge running the entire length of the dorsal margin and turning ventrally at the anterocardinal angle. This ridge is bounded dorsally along its entire length by an equally distinct groove, and ventrally by a fine groove.

The first impression upon examination is that the hingement consists only of a simple groove, but if the specimen is raised ventrally the other components appear.

Remarks.—The specimen examined was a left valve of "*Primitia*" *bonnemai* Swartz (for generic status see Warthin 1948, p. 645) from the Silurian-Gotlandian near Kinteham, Gotland. The holotype is from the same horizon and from a near locale.

Swartz (1936, p. 567) notes a variation in the hinge structure with faint longitudinal grooves separating, as the case may be, two or three low longitudinal ridges.

The orientation here used differs from that of Bassler and Kellett (1934, p. 18) and Swartz (1936, p. 565), and agrees with Triebel's orientation of the genus "*Primitia*" (1941, pl. 11, fig. 134).

One left valve was found with the hingement well preserved.

Figured specimen is Washington University no. 630066.

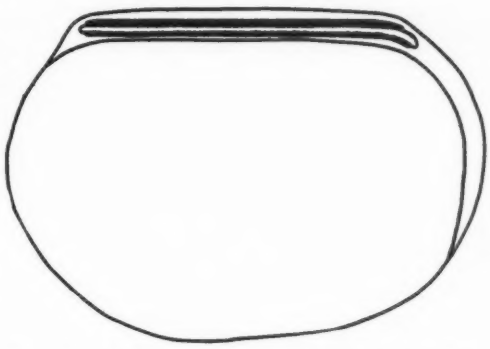


FIG. 3—"*Primitia*" *bonnemai* Swartz, left valve, showing ridge bounded dorsally and ventrally by grooves. Length, 1.02 mm.; height, 0.68 mm. ×60.

Genus PRIMITIOPSIS Jones, 1887

PRIMITIOPSIS BASSLERI Harris, 1931

Primtiopsis bassleri HARRIS, 1931. Oklahoma Geol. Surv., Bull. 55, p. 91, pl. 11, figs. 2a–d; pl. 14, figs. 2a, b.

Hingement.—The hingement of the left valve of *Primitiopsis bassleri* Harris consists of a rounded anterior tooth and an angular, flattened posterior tooth connected by a prominent groove. The hingement of the right valve consists of a rounded anterior socket and an angular posterior socket; the posterior margin of the posterior socket is not as high as other portions of the margin of the socket. A ridge connects the dorsal margins of the two sockets.

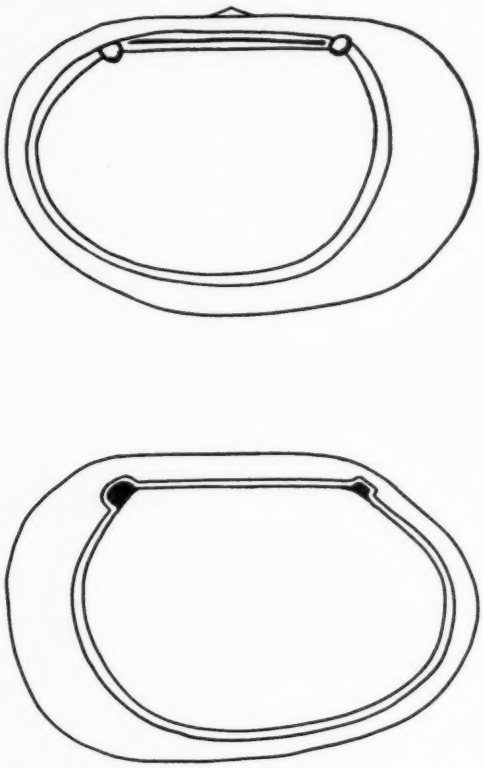
Remarks.—The type species of *Primitiopsis* is *P. planifrons* Jones from the Silurian-Gotlandian of Gotland. The specimens of *P. bassleri* examined are from 125 feet below the top of the Bromide (M. Ordovician) in Oklahoma. *P. bassleri* is common at this horizon and does not occur abundantly at any horizon nearer that of the genotype in the United States.

The orientation is the opposite of that

which has been commonly used. On the basis of the development and the position of the teeth and sockets the orientation has been reversed.

Two left valves and twenty-five right valves were found with well preserved hingement.

Figured specimens are Washington University no. 700001.



FIGS. *4a, b—Primitiopsis bassleri* Harris. *4a* (above), left valve showing anterior and posterior teeth connected by a groove. Length, 0.87 mm.; height, 0.58 mm. ×74. *4b*, right valve showing anterior and posterior sockets and a ridge connecting the dorsal margins of the sockets. Size and magnification as in *4a*.

Genus ERIDOCONCHA Ulrich and Bassler, 1923

ERIDOCONCHA RUGOSA Ulrich and Bassler, 1923

Eridoconcha rugosa ULRICH and BASSLER, 1923. Maryland Geol. Surv., Silurian vol., p. 296, fig. 14.

Hingement.—The hingement of one of the valves consists of a ridge running the length of the dorsal margin. Dorsal to the ridge is a prominent groove, ventral to the ridge is a fine groove. This valve is here arbitrarily called the left-plenate valve [see below]. No hingement was found on the opposite valve.

Species of *Eridoconcha* from the Elkhorn of Fairhaven, Ohio show a similar method of articulation.

Remarks.—This species is the genotype of *Eridoconcha* and was originally described from the Maysville (Upper Ordovician) of Cincinnati, Ohio. The specimens here examined are from 125 feet below the top of the Bromide (Middle Ordovician) in Oklahoma.

There are neither spines, "brood pouches," thinning of the shell wall, differences in thickness, nor dentition to aid in the determination of orientation; there is only a tendency for one end of the valve to be a little more pointed. The pointed end is refered to as the antiplenate and until additional criteria are put forth the valves are regarded as right- and left-plenate.

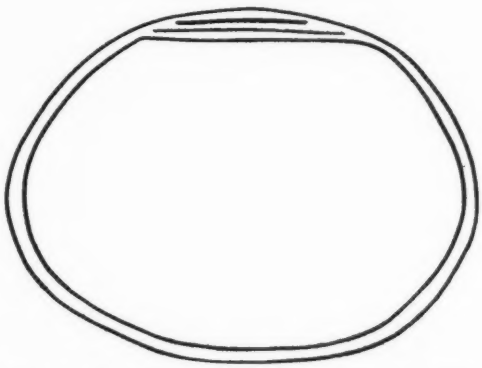


FIG. *5—Eridoconcha rugosa* Ulrich and Bassler, left-plenate valve showing a ridge bounded dorsally and ventrally by grooves. Length, 0.84 mm.; height, 0.62 mm. ×87.

E. A. Schmidt (1941, p. 9) believes that *Eridoconcha* is not an ostracode and advises placing it with the Phyllopoda. Ulrich and Bassler (1923, p. 296) placed *Eridoconcha* in the family Aparchitidae, and Bassler and Kellett (1934, p. 16) place it in the Leperditellidae. In view of its similarity in hingement and the presence of a sulcus, it is here

suggested that *Eridoconcha* be placed in the Primitiidae.

Two left-plenate valves were found with the hingement well preserved.

Figured specimen is Washington University no. 700013.

Genus MILLERATIA Swartz, 1936

MILLERATIA CINCINNATIENSIS (Miller), 1875

Beyrichia cincinnatiensis MILLER, 1875. Cincinnati Quart. Jour. Sci., vol. 2, p. 350, text fig. 25.
Primitia cincinnatiensis (Miller). MILLER, 1889, North American Geol. Pal., p. 561, text fig. 1045.
Milleratia cincinnatiensis (Miller). SWARTZ, 1936, Jour. Paleontology, vol. 10, no. 7, p. 568, pl. 86, figs. 7a–e.

Hingement.—The hingement of the right valve of *Milleratia cincinnatiensis* (Miller) consists of a prominent ridge along the entire length of the dorsal margin; ventral to the ridge is a distinct groove. No hingement

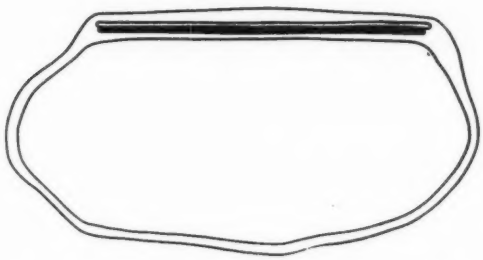


FIG. 6—*Milleratia cincinnatiensis* (Miller), right valve showing a ridge bounded ventrally by a groove. Length, 0.78 mm.; height, 0.36 mm. ×79.

was discernible on the many specimens of right valves.

Remarks.—The genotype of *Milleratia* is *M. cincinnatiensis* from the Richmond Group; the specimens examined are also from the Richmond Group, Waynesville formation at St. Peters, Indiana.

The orientation agrees with that of Swartz (1936). The specimen figured differs in shape from the typical *M. cincinnatiensis* described by Swartz; it is no doubt a dimorphic form of this species.

Two right valves were found with well preserved hingement.

Figured specimen is Washington University no. 700014.

Family TETRADELLIDAE Swartz, 1936

Genus CERATOPSIS Ulrich, 1894

CERATOPSIS CHAMBERSI (Miller), 1874

Beyrichia chambersi MILLER, 1874. Cincinnati Quart. Jour. Sci., vol. 1, p. 234, text fig. 27.
Tetradella chambersi (Miller). ULRICH, 1890, Cincinnati Soc. Nat. Hist. Jour., vol. 13, p. 112.
Ceratopsis chambersi (Miller). ULRICH, 1894, Geol. Minn., vol. 3, pt. 2, p. 676, pl. 46, figs. 19–22.

Hingement.—The hingement of the left valve of *Ceratopsis chambersi* (Miller) consists of faint sockets at the cardinal angles. The sockets have no confining ventral margin.

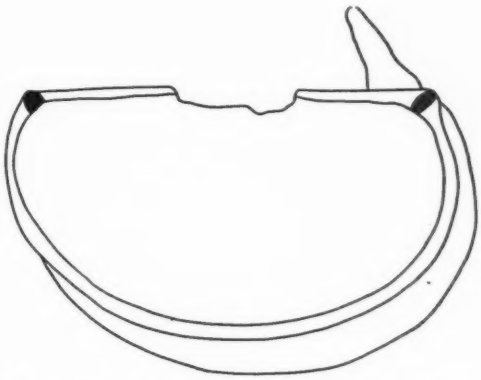


FIG. 7—*Ceratopsis chambersi* (Miller), left valve showing sockets at the cardinal angles. Length, 1.95 mm.; height, 1.10 mm. ×33.

Although a number of specimens were examined no hingement was discernible on the right valves, probably due to poor preservation of the hingeline.

Bonnema (1930, p. 115) notes that *Ceratopsis* is characterized by a groove in the left valve. This could not be confirmed on the specimens examined.

Remarks.—*C. chambersi*, the genotype of *Ceratopsis* was studied. The holotype of this species is from the Eden (Ordovician) of Ohio. The specimens examined are from the same horizon and a near locale, Ripley, Ohio.

The orientation of *Ceratopsis* agrees with that of Triebel (1941, pl. 9, fig. 101), but differs from that of Ulrich and Bassler (1923, p. 310, fig. 20). The prominent dorsal

spine pointing to the antiplenate end of the valve is the basis for the reversal of orientation.

Ten left valves were found with well preserved hingement.

Figured specimen is Washington University no. 700003.

Family DREPANELLIDAE Ulrich and Bassler, 1923

Genus ULRICHIA Jones, 1890

ULRICHIA BITUBERCULATA (M'Coy), 1844

Cythere bituberculata M'COY, 1844. Syn. Char. Carb. Fossils Ireland, p. 165, pl. 23, fig. 10.

Beyrichia bituberculata (M'Coy). JONES and KIRKBY, 1865, Geol. Soc. Glasgow, Tr., vol. 2, p. 220.

Ulrichia bituberculata (M'Coy). JONES and KIRKBY, 1896, Roy. Dublin Soc., Tr., vol. 6, p. 191, pl. 12, fig. 20.

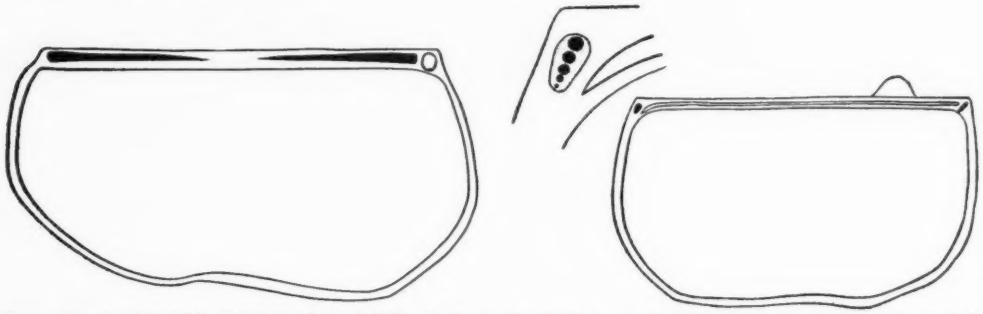
One valve does not appear to be the counterpart of the other; the difference may be due to individual variation or poor preservation.

Remarks.—The type species of *Ulrichia* is *U. conradi* Jones from the Devonian of Canada. The specimens of *U. bituberculata* are from the Carboniferous of Scotland, Williamswood Quarry near Pollockshaws; these specimens were originally identified by John Young in 1866 as *Beyrichia bituberculata* and were studied in his original slides.

The orientation is that of Ulrich and Bassler (1923, p. 298–299) and Bonnema (1930, p. 113).

Two left valves and two right valves were found with well preserved hingement.

Figured specimens are Washington University no. 700004.



FIGS. *8a, b—Ulrichia bituberculata* (M'Coy). Length, 0.82 mm.; height, 0.36 mm. *8a* (above), left valve showing anterior tooth and anterior and posterior grooves. ×64. *8b*, right valve showing anterior and posterior sockets and the ridge along the dorsal margin. ×57. Note enlargement of anterior portion at upper left.

Hingement.—The hingement of the left valve of *Ulrichia bituberculata* (M'Coy) consists of a rounded anterior tooth behind which lies a delicate but distinct groove tapering almost to the center of the valve; from the postcardinal angle another groove tapers along the dorsal margin almost to the center of the valve. The hingement of the right valve consists of an anterior socket (under higher magnification, 100×, this appears as a series of smaller sockets), an elongate posterior socket lying at an angle of 45° to the dorsal margin, and a ridge which occupies the length of the dorsal margin. This ridge turns downward slightly at the anterior socket; at the posterior the ridge meets the center of the posterior socket.

Family HOLLINIDAE Swartz, 1936

Genus HOLLINA Ulrich and Bassler, 1908

HOLLINA KOLMODINI (Jones), 1890

Beyrichia kolmodini JONES, 1890, Geol. Soc. London Quart. Jour., vol. 46, p. 538, pl. 20, fig. 6.

Hollina kolmodini (Jones). ULRICH and BASSLER, 1908, U. S. Nat. Mus., Proc., vol. 35, pl. 42, figs. 5–7. MOORE, 1929, Denison Univ. Bull., Jour. Sci. Lab., vol. 24, p. 100.

Hollinella kolmodini (Jones). BASSLER and KELLETT, 1934, Geol. Soc. America, Special Papers No. 1, p. 333.

Hingement.—The hingement of the right valve of *Hollina kolmodini* (Jones) consists of an anterior and a posterior socket occupying the cardinal angles, and a sharp ridge extending along the dorsal margin of the valve forming the dorsal margins of the sockets.

Although a number of left valves were observed, a description of the hingement is not possible because of their poor preservation.

Remarks.—The type species of *Hollina* is *H. insolens* Ulrich from the Onondaga of the Falls of the Ohio, Louisville, Kentucky. The specimens of *H. kolmodini* examined are from the Hamilton (Devonian) of Thedford, Ontario and are topotypes of that species. Bassler and Kellett (1934, p. 333) refer this species to *Hollinella*, but a comparison of the hingement of these specimens and other species of *Hollina* with the hingement of *Hollinella* as described by Kellett (1929, p. 199) leaves little doubt that *H. kolmodini* should be removed from the genus *Hollinella*. Externally *H. kolmodini* is not closely related to the genotype, but it is similar to other species of *Hollina* believed typical of the genus. *H. kolmodini* is here provisionally placed in the genus *Hollina* until further work ascertains its true position.

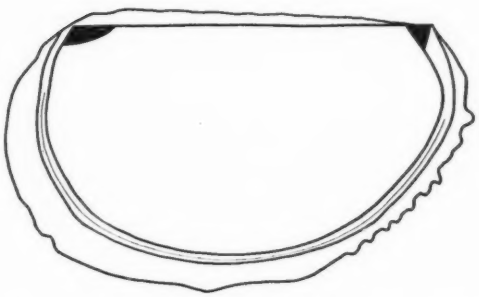


FIG. *9*—*Hollina kolmodini* (Jones), right valve showing anterior and posterior cardinal sockets, the dorsal margin forming a sharp ridge connecting the dorsal side of the sockets. Length, 1.75 mm.; height, 0.94 mm. ×38.

The orientation here used is the opposite of that commonly employed. The presence of spines on the antiplenate margin of the valve indicate that the right-plenate valve is the right valve.

Two right valves were found with well preserved hingement.

Figured specimen is Washington University No. 630124.

Genus CTENOBOLBINA Ulrich, 1890
CTENOBOLBINA PAPILLOSA Ulrich, 1891

Ctenobolbina papillosa ULRICH, 1891. Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 186, pl. 15, figs. 8a–c.

Hingement.—The hingement of the right valve of *Ctenobolbina papillosa* Ulrich consists of a triangular anterior socket and an elongate triangular posterior socket, with a ridge occupying the entire length of the dorsal margin and forming the dorsal margin of the socket. A groove is superimposed on the ridge and becomes indistinct as it nears the cardinal angles.

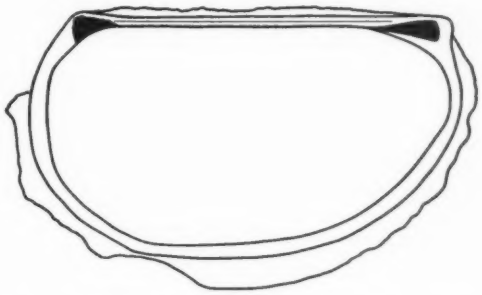


FIG. *10*—*Ctenobolbina papillosa* Ulrich, right valve showing triangular anterior and posterior sockets and the ridge forming the dorsal margin of the sockets. Length, 1.35 mm.; height, 0.81 mm. ×43.

There appears to be variation in the shape of the anterior and posterior sockets. The specimens observed had only a fair degree of preservation.

Remarks.—The type species of *Ctenobolbina* is *C. ciliata* Ulrich from the Trenton (Ordovician) of Cincinnati, Ohio. The specimens of *C. papillosa* examined are from the Onondaga (Devonian) of the Falls of the Ohio, Louisville, Kentucky.

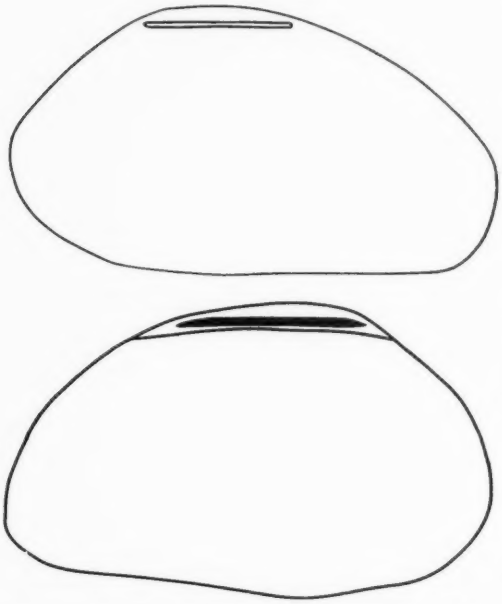
The orientation is that of Ulrich and Bassler (1923, pp. 310–311) and of Bonnema (1930, p. 115). Bonnema notes that a groove is present in the left valve. One right valve was observed with well preserved hingement.

Figured specimen is Washington University no. 630112.

Superfamily CYPRACEAE Dana, 1852
Family THLIPSURIDAE Ulrich, 1894
Genus THLIPSURELLA Swartz, 1932
THLIPSURELLA FOSSATA (Roth), 1929

Thlipsura fossata ROTH, 1929. Jour. Paleontology, vol. 3, no. 4, p. 355, pl. 36, figs. 16a–c.
Thlipsurella fossata (Roth). SWARTZ, 1932, Jour. Paleontology, vol. 6, no. 1, p. 44.

Hingement.—The hingement of the left valve of *Thlipsurella fossata* (Roth) consists of a distinct groove along the entire dorsal margin. The hingement of the right valve consists of a flange-like ridge running the entire length of the dorsal margin.



FIGS. *11a, b—Thlipsurella fossata* (Roth). Length, 1.78 mm.; height, 1.03 mm. ×36. *11a* (above), right valve showing flange-like ridge along dorsal margin. *11b* (below), left valve showing groove along the dorsal margin.

Remarks.—The type species of *Thlipsurella* is *T. ellipsoclefta* Swartz from the Shriver (Oriskany) of Pennsylvania. The specimens of *T. fossata* examined are topotypes from Roth's Haragan (Helderberg) of the famous White Mound, three miles southeast of Dougherty, Oklahoma.

The orientation is that which is generally accepted and used by Roth (1929, p. 355), Swartz (1932), pl. 10, figs. 6–8) and Warthin (1934, p. 216, pl. 1, fig. 14).

Roth in his original description of the species notes that there was no indication of a hinge. After examining 25 specimens, two left valves and five right valves were found with well preserved hingement.

Figured specimens are Washington University no. 700012.

Genus THLIPSURA Jones and Holl, 1869
THILPSURA FURCA Roth, 1929

Thlipsura furca ROTH, 1929. Jour. Paleontology, vol. 3, no. 4, p. 356, pl. 37, figs. 18a–c.

Hingement.—The hingement of the left valve of *Thlipsura furca* Roth consists of a groove along the entire length of the dorsal margin. The hingement of the right valve consists of a flange-like ridge along the dorsal margin.

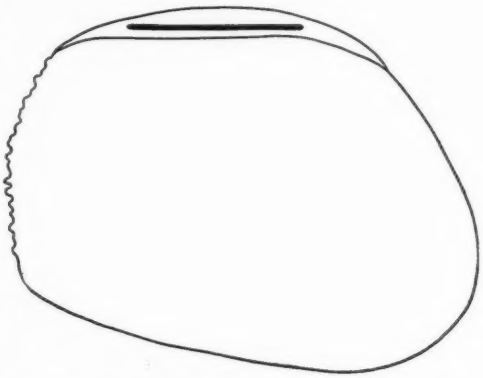


FIG. *12—Thlipsura furca* Roth, left valve showing groove along the dorsal margin. Length, 1.04 mm.; height, 0.73 mm. ×60.

Remarks.—The type species of *Thlipsura* is *T. corpulenta* Jones and Holl from the Wenlock (Silurian) of England. The specimens of *T. furca* examined are topotypes.

The orientation here used is the opposite of that employed by Roth. The specimens were reversed because of the presence of spines on the antiplenate margin of the valve and also to agree with the other thlipsurids which show similar hingement. Although generally lobe-like, the surface ornamentation in some individuals attains a spine-like appearance and points to the antiplenate end.

Roth in his original description of the species notes that no hingeline is discernible. Examination of a number of specimens revealed two left valves and three right valves with well preserved hingement.

Figured specimen is Washington University no. 700005; opposite valve is no. 700006.

Genus PHANASSYMETRIA Roth, 1929
PHANASSYMETRIA TRISERRATA Roth, 1929

Phanassymetria triserrata ROTH, 1929. Jour. Paleontology, vol. 3, no. 4, p. 358, pl. 37, figs. 20a–c.

Hingement.—The hingement of the left valve of *Phanassymetria triserrata* Roth consists of a distinct groove extending the entire length of the dorsal margin. The hingement of the right valve consists of a delicate elongate anterior socket and a ridge which occupies the entire length of the dorsal margin. This ridge forms the dorsal margin of the socket.

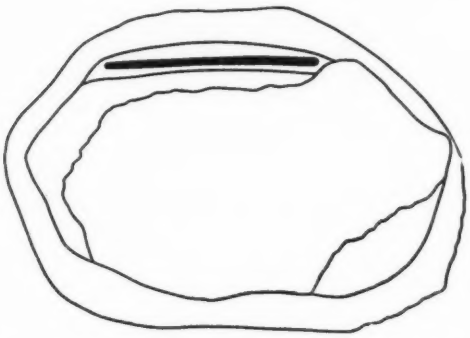


FIG. *13—Phanassymetria triserrata* Roth, left valve (partly filled with matrix) showing groove along the dorsal margin. Length, 1.18 mm.; height, 0.78 mm. ×52.

Remarks.—*Phanassymetria triserrata* is the type species of *Phanassymetria* and the specimens examined are topotypes.

Roth in his original description of the genus "arbitrarily chose" the anterior and posterior end. The orientation is opposite from that employed by Roth because of the relative shape, position and development of the hinge components.

Roth remarks in his original description that the hinge is "very simple." The writer found five right valves and four left valves with well preserved hingement.

Figured specimen is Washington University no. 700009.

Genus ROTHELLA Wilson, 1935
ROTHELLA RECTA (Roth), 1929

Dizygopleura recta ROTH, 1929. Jour. Paleontology, vol. 3, no. 4, p. 344, pl. 36, figs. 8a–c.
Rothella recta (Roth). WILSON, 1935, Jour. Paleontology, vol. 9, no. 8, p. 643.

Hingement.—The hingement of the left valve of *Rothella recta* (Roth) consists of a distinct groove along the entire length of the dorsal margin. The hingement of the right valve consists of an elongate anterior and posterior socket occupying the cardinal angles with indistinct ventral borders and a ridge along the length of the dorsal margin. The large size of the posterior component of Fig. 14 is due to the composite nature of the drawing.

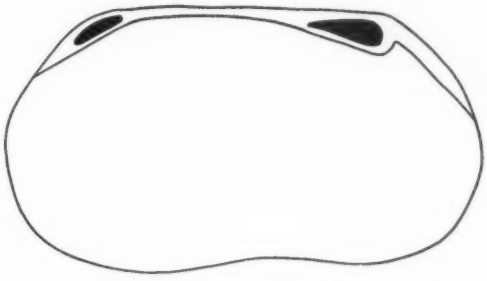


FIG. *14—Rothella recta* (Roth), right valve showing elongate anterior and posterior sockets and a ridge which occupies the dorsal margin. This is a composite view of many positions of the valve. Length, 1.54 mm.; height, 0.69 mm. ×41.

Remarks.—The genotype of *Rothella* is *R. recta* from the Haragan of White Mound, three miles southeast of Dougherty, Oklahoma. The specimens examined are topotypes.

The orientation is that of Wilson (1935, p. 643). One left valve and two right valves were found with well preserved hingement. *R. obliqua*, below, has identical hingement. The right valve of *R. recta* and the left valve of *R. obliqua* are figured because of their excellent preservation of hingement.

Figured specimen is Washington University no. 700015.

ROTHELLA OBLIQUA (Roth), 1929

Dizygopleura obliqua ROTH, 1929 Jour. Paleontology, vol. 3, no. 4, p. 346, pl. 36, figs. 9a, b.
Rothella obliqua (Roth). WILSON, 1935, Jour. Paleontology, vol. 9, no. 8, p. 643.

Hingement.—The same as *Rothella recta* (Roth).

Remarks.—The type species of *Rothella* is *R. recta* (Roth) from the Haragan of White Mound, three miles southeast of Dougherty, Oklahoma. The specimens of *R. obliqua* examined are topotypes.

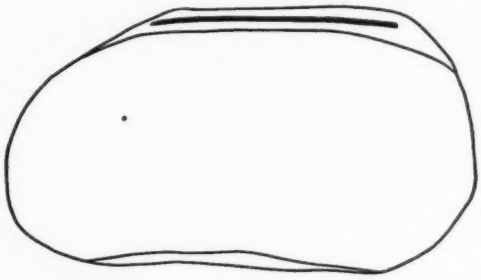


FIG. *15*—*Rothella obliqua* (Roth), left valve showing groove along the dorsal margin. Length, 1.56 mm.; height, 0.70 mm. ×41.

Two left valves and two right valves were found with well preserved hingement.

Figured specimen is Washington University no. 700010.

Genus EUCRATERELLINA Wilson, 1935

EUCRATERELLINA RANDOLPHI Wilson, 1935

Eucraterellina randolphi WILSON, 1935. Jour. Paleontology, vol. 9, no. 8, p. 640.

Hingement.—The hingement of the right valve of *Eucraterellina randolphi* Wilson consists of a groove along the dorsal margin. The hingement of the left valve consists of a ridge along the entire length of the dorsal margin.

Remarks.—The genotype of *Eucraterellina* is *E. randolphi* from the Birdsong (Lower Devonian) of Tennessee; the specimens of *E. randolphi* examined are from the Haragan (Lower Devonian) of White Mound, three miles southeast of Dougherty, Oklahoma. Both formations are New Scotland in age. This is the first reference to *E. randolphi* from the Haragan.

The orientation differs from that used by Wilson (1935, p. 640); it is here reversed so that the hinge would be posterior. *E. randolphi* although differing in hingement from the other thlipsurids is retained in this family because of its shape and ornamentation. Further investigation may reveal that it should be placed in another family.

One right valve and two left valves with well preserved hingement were found. *E. moorei*, below, has identical hingement, and it was figured in place of *E. randolphi* because of better preservation.

Specimens are Washington University no. 700007.

EUCRATERELLINA MOOREI (Roth), 1929

Craterellina moorei ROTH, 1929. Jour. Paleontology, vol. 3, no. 4, p. 362, pl. 37, figs. 22a, b.
Thlipsurella moorei (Roth). SWARTZ, 1932, Jour. Paleontology, vol. 6, no. 1, p. 45.
Eucraterellina moorei (Roth). WILSON, 1935, Jour. Paleontology, vol. 9, no. 8, p. 640.

Hingement.—The same as *Eucraterellina randolphi* Wilson.

Remarks.—The type species of *Eucraterellina* is *E. randolphi* from the Birdsong of Tennessee. The specimens of *E. moorei* which were examined are topotypes from the Haragan of Oklahoma.

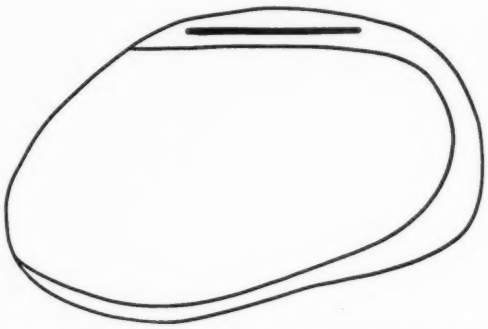


FIG. *16*—*Eucraterellina moorei* (Roth), right valve showing groove along the dorsal margin. Length, 0.84 mm.; height, 0.41 mm. ×75.

The orientation is that of *E. randolphi*.

Four right valves and six left valves with well preserved hingement were found.

Figured specimen is Washington University no. 700008.

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MIOCENE OSTRACODA FROM VENEZUELA

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ABSTRACT—Thirty-one species of Ostracoda are reported from the Miocene of the Maracaibo Basin. Eleven of the species have not been described before. The remaining species show that strong affinity exists between the La Rosa formation and the Miocene (more especially the middle Miocene) from elsewhere in the Caribbean Region or the Gulf and Atlantic Coastal Plains of the United States.

INTRODUCTION

THE present paper deals with the Ostracoda contained in the Miocene La Rosa formation of the Maracaibo basin. This formation has been encountered in many wells of the Bolivar coastal oil fields and it is found outcropping near the eastern border of the State of Zulia. Especially in the Quiroz region the La Rosa formation comes to the surface from underneath the "Younger-Tertiary" cover in large areas, and the new species described have their type localities in this region, see the accompanying sketch map.

Manger (1938) gives the following nomenclature for the Oligocene and younger subsurface formations as used by the different oil companies in the Bolivar coastal area:

TABLE 1. STRATIGRAPHIC NOMENCLATURE USED IN THE BOLIVAR COASTAL AREA

Lago Petroleum Co.	V. O. C. Ltd.	Mene Grande Oil Co.
Maracaibo formation La Puerta formation	Maracaibo formation or Younger Tertiary series	El Milagre formation La Villa-La Puerta formation
Upper La Rosa formation	Lagunillas formation	Lagunillas formation
	Upper	
Lower La Rosa formation	La Rosa formation	La Rosa formation
	Lower	
Icotea formation	Icotea formation	Icotea formation

The name La Rosa has been used for different formations. Moreover, various ages have been attached to the formations by different authors, as may be seen in Table 2.

The name La Rosa formation as used in the present paper comprises the Upper La Rosa of the V. O. C. in the Bolivar coastal fields (Manger, 1938), and the Upper and Lower La Rosa from the Quiroz area (Sutton, 1946). The La Rosa fauna shows a strong affinity with the Miocene of other parts of the Caribbean region, and the Gulf and Atlantic Coastal Plains of the United States, and more especially has many species in common with the middle Miocene of Florida (Howe and grad. students, 1935). The Ostracode fauna of the Upper and Lower La Rosa of the Quiroz area are identical except for *Pterygocythereis americana* (Ulrich and Bassler) which appears to be confined to the Lower La Rosa. This species does not occur in the La Rosa of the Bolivar coast. It has been found in the Chipola Miocene of Florida (range chart by Hendee Smith) and the lower middle Miocene Choptank of Maryland. In the middle Miocene of Florida (Shoal River) this species seems to be replaced by a closely related form, described under the same name by Howe & grad. stud. 1935. The occurrence of *Pterygocythereis americana* (Ulrich & Bassler) to-

gether with middle Miocene (Arca-zone of the Choctawhatchee of Florida) species in loc. 11 suggests a lower middle Miocene age for the Lower La Rosa of the Quiroz area; the Upper La Rosa of this region and the La Rosa of the Bolivar coast (subsurface) may consequently be higher middle Miocene.

Tamare and Quebrada La Mesa to the north. U. La Rosa.
8. Outcrop of ?U. La Rosa in Quebrada Pitonal 750 m. from confluence with Rio Tamare.
9. Pit in L. La Rosa at the border of Quebrada Los Negros.
10. Pit in L. La Rosa in same pit line as loc. 9. This line runs to the north from a place at the bank of the Rio Tamare, 1.5 km. from confluence with Quebrada El Cachimbo.

TABLE 2. CORRELATION OF THE LA ROSA AND ASSOCIATED FORMATIONS

		Senn, 1940 E. Zulia	Liddle, 1946 Bolivar coast		Sutton, 1946 E. Zulia	
Miocene	U.	La Puerta	La Puerta/La Villa		La Puerta	
	M.		Lagunillas (subsurface)		Lagunillas	
	L		La Rosa	Santa Barbara surface	La Rosa (Quiroz)	Upper / Lower
U. Oligocene		Lagunillas	subsurface		(hiatus)	
		La Rosa				
		Icotea	Icotea		Icotea	

LOCATION OF SAMPLES

The surface samples studied have been collected by P. Bitterli, J. J. Hermes, P. Kiewiet de Jonge and L. Kieboom, geologists with the Shell Caribbean Petroleum Company. New types have been described from these localities, which are listed below and are indicated on the sketch map. More material came from wells in the Bolivar coastal oil fields.

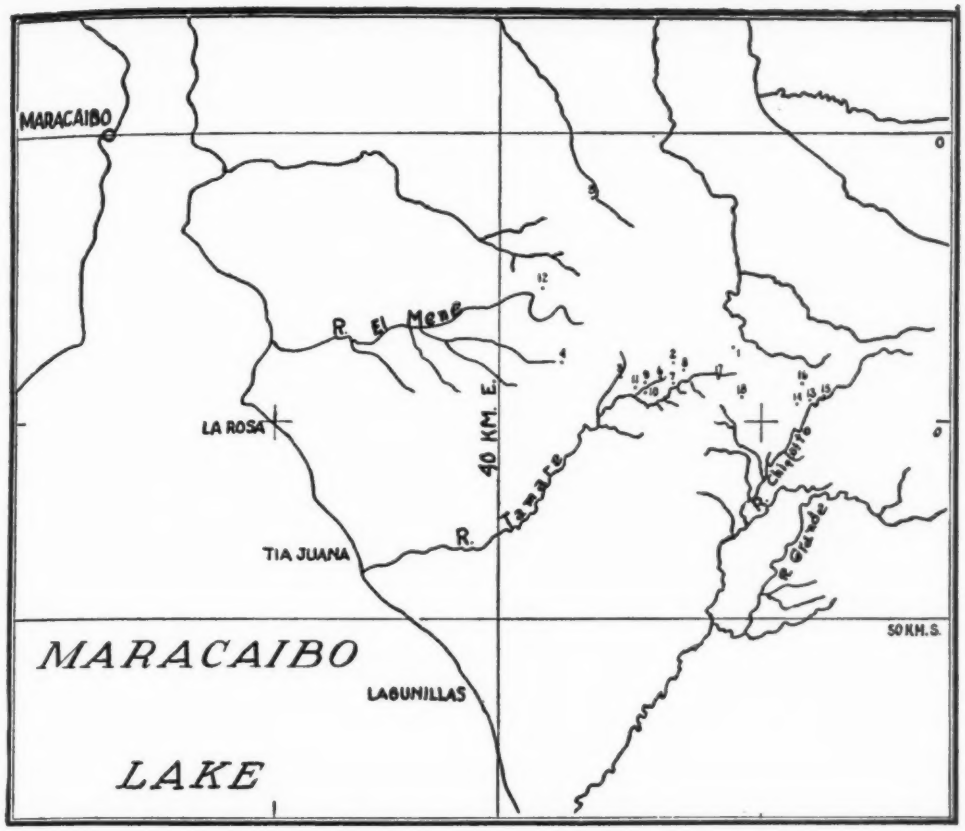
1. Outcrop of La Rosa in headwaters of Quebrada Ceibita.
2. Outcrop of ?U. La Rosa in small quebrada, not indicated on the sketch map.
3. Outcrop of L. La Rosa in Quebrada Guacamayo 3.5 km. upstream from confluence with Rio Tamare.
4. Outcrop of U. La Rosa in Quebrada Olaya, 2.5 km. due W. from El Cuarenta on the road from El Concejo to La Rosa and Lagunillas, 40 km. from La Rosa.
5. Pit in U. La Rosa near the bank of the Rio Palmar, about 2.5 km. downstream from confluence with Quebrada Santa Isabel.
6. Outcrop of U. La Rosa in Quebrada Los Negros (tributary to Rio Tamare) about 50 m. from upper end.
7. Augerhole in augerline from confluence Rio
11. Outcrop of L. La Rosa in Quebrada Vigia 500 m. upstream from confluence with Quebrada Los Negros, which confluence lies about 500 m. from the confluence of Quebrada Los Negros and Rio Tamara.
12. Augerhole, the location of which cannot be given otherwise than by referring to the sketch map.
13. Two outcrops of U. La Rosa, close together in Quebrada Lambedero about 1 km. upstream from Rio Chiquito.
14. Two outcrops of U. La Rosa (about 100 m. apart) in Quebrada Juanita.
15. Three outcrops of L. La Rosa, close together in Caño Resbaloso, about 6.5 km. upstream from Rio Chiquito.
16. Outcrop of U. La Rosa in upper end of Quebrada Lembedero.
17. Outcrop of ?U. La Rosa, 200 m. upstream in tributary of Quebrada Ceibita, into which this small quebrada flows at 150 m. from confluence with Rio Tamare.
18. Outcrop of ?U. La Rosa in Rio Retirada, 2.1 km. upstream from confluence with Quebrada Tomás.

ACKNOWLEDGMENTS

The author wishes to express his thanks to the Shell Caribbean Petroleum Company for allowing the results of this study

TABLE 3. OCCURRENCE OF VENEZUELAN MIOCENE OSTRACODA. Numbers 1–18 refer to sample localities. A, middle Miocene of Panama. B, Miocene of Guatemala. C, Miocene of Cuba. D, Choptank of Maryland. E, Calvert of Maryland. F, Miocene of Mississippi. G, upper Miocene of North Carolina. H, Oligocene of Louisiana. I, Oligo-miocene, Gulf Coast. J, Chipola of Florida. K, Shoal River and Oak Grove of Florida. L, Yoldia zone of Choctawhatchee of Florida. M, Arca zone. N, Cancellaria-Ecphora zone.

	Locality																	Other Occurrences													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Cytherella sp.		×	×	×	×	×	×			×	×	×	×	×	×	×		×													
Cytherelloides leonensis Howe											×		×		×	×		×	—	—											—
Cytherelloides clavaensis n. sp.			×	×	×																										
Bairdia sp.		×						×									×														
Bairdoppilata triangularis Edwards	×																														
Paracyprideis vicksburgensis (Howe & Law)												×	×								—					—					
Haplocytheridea larosaensis n. sp.			×		×	×	×			×		×																			
Haplocytheridea curta n. sp.										×																					
Anomocytheridea ovata Mincher					×	×	×					×	×		×	×								—							
Cytherideis howei v.d. Bold										×	×									—	—										
Cythereis vicksburgensis Howe & Law		×																			—					—					
Cythereis pipkinensis Stephenson																	×										—	—			
Cythereis tschoppi v.d. Bold					×															—	—										
Cythereis exanthemata var. gomillionensis Howe & Ellis		×	×	×	×			×	×	×	×	×	×	×	×	×		×		—	—				—		?	?	—	—	—
Cythereis vaughani (Ulrich & Bassler)		×			×														—	—	—	?	—		—					—	—
Cythereis variabilocostata n. sp.	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×		×													
Pterygocythereis americana (Ulrich & Bassler)			×							×	×				×							—					—				
Leguminocythereis sp.										×																					
Buntonia tamarense n. sp.											×																				
Favella rugipunctata (Ulrich & Bassler)			×	×	×	×									×	×				—	—		—		—				—	—
Cativella navis Coryell & Fields		×	×	×	×	×								×	×	×		×	—	—									—	—
Cativella? crassa n. sp.			×											×																	
Basslerites miocenicus (Howe)			×	×	×	×				×	×	×		×	×	×		×	—	—	—									—	—
Cytheromorpha warneri Howe & Spurgeon		×		×	×		×			×	×	×	×		×			×			—		—					—	—	—
Loxoconcha reticulata Edwards				×							×	×													—						
Loxoconcha antillea v.d. Bold		×			×			×			×	×									—	—									
Cytheropteron subreticulatum v.d. Bold																					—									—	—
Cytherura sp.				×		×	×											×													
Pellucistoma magniventra Edwards					×				×	×	×				×										—				—	—	
Pellucistoma kendengensis (Kingma)					×					×		×			×	×		×													
Limnocythere venezolana n. sp.												×																			



Map of collecting localities east of Lake Maracaibo. Primary coordinates are based from Maracaibo Cathedral, secondary coordinates from La Rosa.

to be published. Through the courtesy of R. W. Barker (senior paleontologist with S.C.P.C.) the writer was in a position to study an ostracode collection from the Miocene of Florida, and the range of the species as determined by Hendee Smith. H. V. Howe of Louisiana State University donated three slides containing specimens of *Pterygocythereis cornuta* var. *americana* (Ulrich & Bassler) which helped to clear up the uncertainty existing about this species. Moreover the author received from Dr. Howe, through the courtesy of L. Weingeist, a collection of samples from the Gulf Coast Tertiary, which were of the utmost importance, since they permitted direct comparison of many Venezuelan species with similar species from the Gulf Coast.

ILLUSTRATIONS AND TYPES

The species newly described in this paper have been photographed with a simple apparatus consisting of an inclined eyepiece binocular microscope, combined with the bellows-assemblage of a Kodak Precision enlarger model B, fitted with a camera-back adaptor. This apparatus gave fair results in case of not too small and not too badly preserved specimens. It had, of course, the disadvantage of a shallow focal depth; however, no objective with a diaphragm which could offer an improvement was available. The writer used Kodak Superspeed Ortho Portrait sheetfilm, since it was the only suitable kind of film available in Maracaibo.

The types upon which the new species are

based have been deposited in the Louisiana State University Museum, Baton Rouge, Louisiana.

SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latreille
Suborder PLATYCOPA Sars
Family CYTHERELLIDAE Sars, 1865
Genus CYTHERELLA Jones, 1849

CYTHERELLA sp.
Plate 18, figures 1 a–e

A species of this genus occurs regularly in the La Rosa formation. It shows a strong sexual dimorphism, common in *Cytherella*.

Female.—Carapace ovate, highest slightly behind the middle. Widest in posterior half, slightly compressed anteriorly, with a characteristic shallow longitudinal depression just below and in front of the greatest height. Posterior end rounded in dorsal view. In lateral view anterior end regularly rounded with a narrow carina in the left valve, partly obscuring the overlap of the right valve. Dorsal margin arched, somewhat flattened in anterior half. Posterior end evenly rounded, ventral margin convex. Overlap of the right valve strongest ventrally and middorsally; dorsal and ventral margin are flatter in left valve.

Male.—Elongate ovate, highest in front of the middle. Dorsal margin convex, sloping downward into the obliquely rounded posterior end. Anterior end evenly rounded, ventral margin slightly convex.

Dimensions (mm.):

female: L, 0.69; H, 0.49; W, 0.38
male: L, 0.60; H, 0.37; W, 0.26

The species is very similar in appearance to *Cytherella ovata* (Roemer) (Alexander, 1932, p. 303, Pl. 28, fig. 1, 2) but is characterized by the peculiar dorsal depression in the female. *Cytherella texana* Stadnichenko (see Stephenson, 1946, p. 307, Pl. 42, fig. 8, 9) does not show such a depression. *Cytherella atrata* Tolmachoff (1934, p. 283, Pl. 39, fig. 11, 12, non fig. 13, 14) from the Colombian Miocene may be identical with the Venezuelan species, but it is preferred not to name this species because of its common "Cytherella-type."

Type specimens.—H. V. Howe collection no. 4024.

CYTHERELLOIDEA LEONENSIS Howe

Cytherelloidea leonensis HOWE, 1934, Jour. Paleontology, vol. 8, p. 34, pl. 5, fig. 9.
Cytherelloidea leonensis Howe, CORYELL and FIELDS, 1937, Am. Mus. Novitates, 956, p. 2, fig. 1a–c.
Cytherelloidea leonensis Howe. v. d. BOLD, 1946, Contr. Study Ostr., p. 62, pl. 9, fig. 23.

This species has been found in the La Rosa in both well and surface samples.

CYTHERELLOIDEA OLAYAENSIS van den Bold, n. sp.
Plate 18, figures 2 a, b

Carapace elongate subrectangular, very slightly higher in front than behind. Dorsal margin nearly straight, ventral margin very slightly convex, parallel to the dorsal margin; anterior and posterior ends broadly and almost evenly rounded. Ornamentation consists of a weak marginal rim, lying close to the margin except in the posterior end, where it is more pronounced and about vertical. From this posterior ridge two longitudinal ridges extend forward; the upper one is very short and faint, the lower one parallels the ventral margin, bends upward near the anterior end and joins the dorsal marginal ridge just behind the greatest height. Posterior to this the dorsal ridge is divided into two parallel ridges. The surface between the ridges is finely reticulate. Dorsal view narrow; anterior end compressed, greatest width at the posterior vertical ridge.

Dimensions (mm.): L, 0.56; H, 0.34; W, 0.19.

In not perfectly preserved specimens the anterior ridge is difficult to discern and the surface is almost smooth, so that these specimens may be confused with *Cytherelloidea leonensis* Howe, which is the only species comparable. This species is rare throughout the La Rosa.

Type locality.—Locality 4. Type specimens: H. V. Howe collection no. 4023.

Suborder PODOCOPA Sars
Family BAIRDIIDAE Sars, 1887
Genus BAIRDIA McCoy, 1844

BAIRDIA sp.
Plate 19, figure 3

Carapace elongate bairdioid; anterior cardinal angle rather pronounced; antero-

dorsal margin nearly straight, posterodorsal margin slightly sinuate. Dorsal margin arched as a whole, highest in the middle. Posterior end more or less pointed. Ventral margin regularly convex. Overlap of left valve strongest ventrally and mid-dorsally.

Dimensions (mm.): L, 0.05; H, 0.53; W, 0.37.

This species is more elongate than *Bairdia antillea* v.d. Bold (1946, p. 59, pl. 1, fig. 2). *Bairdia verdesensis* LeRoy (1943, p. 358, pl. 60, fig. 5–9) has a much blunter posterior end.

The species occurs scattered in the La Rosa. Type specimens, H. V. Howe collection no. 4022.

Genus BAIRDOPPILATA Coryell, Sample & Jennings, 1935

BAIRDOPPILATA TRIANGULARIS Edwards

Bairdoppilata triangularis EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 507, pl. 85, fig. 5–7.

This species occurs occasionally in the La Rosa of the Bolivar coast. It was only found in one surface sample in the Quiroz area.

Family CYTHERIDAE Baird 1850

Genus HAPLOCYTHERIDEA Stephenson 1936

HAPLOCYTHERIDEA LAROSAENSIS van den Bold, n. sp.

Plate 19, figures 2 a, b

Female.—Carapace elongate, greatest height anterior to the middle. Anterior end evenly rounded, dorsal margin gently arched, ventral margin slightly convex, posterior end obliquely rounded in the left valve. In the right valve the posterior end is more strongly pointed ventrally and slightly thickened, so that it may even obscure the ventral margin of the overlapping left valve. Strongest overlap midventrally, regular overlap in the rest of the margin. Greatest width in posterior half of the carapace. Outline in dorsal view elliptical.

Male.—More elongate than female and more strongly pointed posteroventrally. Ventral margin in the left valve slightly concave near the posterior end. Hinge in both sexes typical for the genus.

Dimensions (mm.):

female: L, 0.87; H, 0.49; W, 0.35
male: L, 0.89; H, 0.45; W, 0.32

There is a strong external resemblance to "*Leptocytheridea*" *choctawhatchensis* (Howe & Stephenson) (Howe & grad. stud., 1935, p. 9, pl. 2, fig. 11; pl. 4, fig. 9), but since *Leptocytheridea* probably represents young moults, and the adult form has not been determined, it has been thought necessary to name the species. It is common in Upper and Lower La Rosa.

Type locality.—Loc. 12. Type specimens in H. V. Howe collection no. 4021.

HAPLOCYTHERIDEA CURTA van den Bold, n. sp.

Plate 19, figures 1 a–e, text fig. 1

Carapace large, more or less truncate behind. Sexual dimorphism very strong.

Female.—Short, almond-shaped, highest just behind the middle. Anterior end rounded, dorsal margin arched, ventral margin convex, posterior end obliquely rounded, almost truncate. Left valve rather different in shape from the right one, which is more angular, obtusely angled at greatest height and steeply truncate behind. Anterior end in the right valve denticulate. Dorsal view elliptical, greatest width about the middle, posterior end slightly more rounded than anterior end. Overlap of left valve rather regular, strongest dorsally and midventrally.

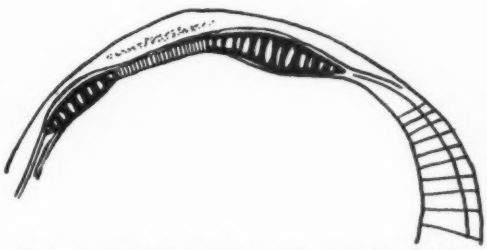


FIG. 1—*Haplocytheridea curta*, van den Bold, n. sp. Hinge of left valve, ×65.

Male.—Left valve almond-shaped, more elongate than the female. Right valve distinctly more angular than the female right valve. Both sexes show a small downward-pointing spine at the posteroventral angle of the right valve.

Hinge typical for the genus, consisting of eight cusps in the anterior dental area and seven in the posterior one. Marginal area

of moderate width, line of concrescence and inner margin coincide, radial pore-canals numerous. In the left valve a groove along the entire free border is surrounded on the outside by a strong lip for reception of the right. Above the hingeline, which forms the chord of the circle segment shaped by the dorsal margin, a shallow smooth groove is found which makes articulation possible.

Dimensions (mm.):

female: L, 0.94; H, 0.64; W, 0.47
male: L, 1.15; H, 0.73; W, 0.46

The species shows some affinity to *Haplocytheridea karlana* Stephenson (1938, p.132, pl. 23, fig. 3) and to *Haplocytheridea texana* Stephenson (1944, p. 160, pl. 28, fig. 14), but is more angular, especially in the right valve.

An ostracode from the Colombian Miocene figured by Tolmachoff (1934, pl. 39, fig. 13, 14, non fig. 11, 12) may be identical. As the name *Cytherella strata* Tolmachoff should be restricted to the species figured in fig. 11 and 12, this name cannot be applied to the La Rosa species.

The species occurs abundantly in some wells of the Bolivar coast.

Type locality.—Loc. 10. Type specimens in H. V. Howe collection No. 4020.

Genus ANOMOCYTHERIDEA Stephenson, 1938
ANOMOCYTHERIDEA OVATA Mincher

Anomocytheridea ovata MINCHER, 1941, Jour. Paleontology, vol. 15, p. 342, pl. 46, fig. 2a–e.

This species accompanies *Haplocytheridea larosaensis* n. sp. in the La Rosa formation. They nearly always occur together.

Genus PARACYPRIDEIS Klie, 1929
? PARACYPRIDEIS VICKSBURGENSIS (Howe & Law)

Krithe vicksburgensis HOWE and LAW, 1936, Louisiana Dept. Cons. Geol. Bull. 7, p. 73, pl. 6, fig. 12, 13.
Paracyprideis? vicksburgensis (Howe and Law), V. D. BOLD 1946, Contr. Study Ostr., p. 78, pl. 7, fig. 4.

This species from the Oligocene of Louisiana was recorded by the present author from the Miocene of Cuba (v. d. Bold, 1946). It has been found occasionally in the La Rosa of the Maracaibo basin.

Genus CYTHERIDEIS Jones, 1856
CYTHERIDEIS HOWEI v. d. Bold

Cytherideis howei V. D. BOLD 1946, Contr. Study Ostr., p. 88, pl. 7, fig. 9.

The species occurs occasionally in the La Rosa, possibly only in the lower part, as it has not been found in the wells of the Bolivar coast.

Genus CYTHEREIS Jones, 1849[1]
CYTHEREIS VICKSBURGENSIS Howe

Cythereis vicksburgensis HOWE, Howe and Law, 1936, Louisiana Dept. Cons. Geol Bull. 7, p. 34, pl. 4, fig. 4; pl. 5, fig. 1, 3.
Cythereis vicksburgensis Howe, V. D. BOLD, 1946, Contr. Study Ostr., p. 69, pl. 10, fig. 5.
Cythereis bicarinata SWAIN, 1946, Jour. Paleontology, vol. 20, p. 376, pl. 54, fig. 7a–d; pl. 55, fig. 1a–e.

Specimens of *Cythereis bicarinata* Swain from the Ocala limestone of Florida have been compared with specimens of *Cythereis vicksburgensis* Howe from the Red Bluff of Louisiana. Though they are in a completely different state of preservation, the writer feels convinced that the two species are identical. The range of this species is most probably upper Eocene-Recent. Only a few specimens of this species have been found in the La Rosa.

CYTHEREIS PIPKINENSIS Stephenson

? non Cythereis sp. 19 HOWE, 1934, Guidebook 11th fieldtrip Shreveport Geol. Soc., pl. 1, fig. 19–21.
Cythereis hannai STEPHENSON, 1944, Jour. Paleontology, vol. 18, p. 157, pl. 28, fig. 11, 12.
non Cythereis hannai ISRAELSKY, 1929, Arkansas Geol. Surv., Bull. 2, p. 16, pl. 4A, fig. 1a–c.
Cythereis pipkinensis STEPHENSON, 1945, Jour. Paleontology, vol. 19, p. 411.

The species figured by Howe (1934) is much closer to *Cythereis tschoppi* v. d. Bold

[1] The name of *Cythereis* has not been replaced by *Trachyleberis* Brady as proposed by Sylvester-Bradley (Journal of Paleontology, vol. 22, no. 6, 1948), as in the species from the Venezuelan Miocene no crenulation of the median hinge-element in the left valve has been observed. It is not known whether this is due to subsequent disappearance of the minute crenulations, or to non-existence of crenulations in the species described here. In the latter case still another genus would have to be erected in order to receive many Tertiary species hitherto assigned to *Cythereis*.

(1946). Both forms (*Cythereis pipkinensis* and *Cythereis tschoppi*) have been found by the author in the Chickassawhay of the Gulf coast; they are possibly not more than variants.

This species has been found only at loc. 17.

CYTHEREIS TSCHOPPI v. d. Bold

? Cythereis sp. 19 HOWE, 1934, Guidebook 11th fieldtrip Shreveport Geol. Soc., pl. 1, fig. 19–21.
Cythereis tschoppi v. d. BOLD, 1946, Contr. Study Ostr., p. 93, pl. 10, fig. 14.

This species differs from *C. pipkinensis* Stephenson (1945) in having a more prominent ventral ridge and a stronger subcentral tubercle. *Cythereis pipkinensis* is more strongly sculptured.

This species has been found in one surface sample and in some well samples from the Bolivar coast.

CYTHEREIS EXANTHEMATA (Ulrich & Bassler) var. GOMILLIONENSIS Howe & Ellis

Cythereis exanthemata var. *gomillionensis* HOWE and ELLIS, Howe & grad. stud., 1935, Florida Dept. Cons. Geol. Bull. 13, p. 19, pl. 1, fig. 6–12; pl. 4, fig. 3.
Cythereis exanthemata var. *gomillionensis* Howe and Ellis, EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 521, pl. 85, fig. 31, 32.
Cythereis exanthemata var. *gomillionensis* Howe and Ellis, v. d. BOLD, 1946, Contr. Study Ostr., p. 88, pl. 9, fig. 19.

This species is very common throughout the La Rosa formation.

CYTHEREIS VAUGHANI (Ulrich & Bassler)

Cythere vaughani ULRICH and BASSLER, 1904, Maryland Geol. Surv., Miocene, p. 109, pl. 38, fig. 25.
Cythereis vaughani (Ulrich and Bassler), HOWE & grad. stud., 1935, Louisiana Dept. Cons. Geol. Bull. 13, p. 25, pl. 3, fig. 24–25; pl. 4, fig. 3.
Cythereis vaughani (Ulrich and Bassler), CORYELL and FIELDS, 1937, Am. Mus. Novitates, 956, p. 9, fig. 10.
Cythereis vaughani (Ulrich and Bassler), EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 522, pl. 85, fig. 27, 28.
Cythereis vaughani (Ulrich and Bassler), v. d. BOLD, 1946, Contr. Study Ostr., p. 88, pl. 10, fig. 1.

This species has been found in the La Rosa of the Bolivar coast and in Upper and Lower La Rosa of the Quiroz area.

CYTHEREIS VARIABILOCOSTATA van den Bold, n. sp.
Plate 18, figures 3a, b

Carapace small, thick-shelled, subquadrate, three-ribbed. Highest at anterior cardinal angle in left valve. Anterior end in right valve only very slightly higher than posterior cardinal angle. Dorsal and ventral margin almost straight and converging very slightly posteriorly. Anterior end obliquely rounded, bearing a row of spines and a marginal ridge, which continues parallel to the ventral margin, being most conspicuous at its posterior end, about ¼ of length from the posterior end of the carapace. Parallel to this ridge runs another one, joining it at its posterior end. A slightly curved dorsal ridge obscures the dorsal margin. A slightly oblique median ridge runs forward from just below the posterior cardinal angle. It divides in the center of the carapace into two slightly diverging ridges. The surface between the ridges is reticulate. Posterior end triangular, laterally compressed; dorsal part concave, ventral part rounded and bearing a few spines. Hinge typical for the genus. Marginal area moderately broad; line of concrescence and inner margin coincide; pore-canals numerous in both ends.

The species may show some variation in the pattern of the ridges. Sometimes these ridges are hardly raised at all, and appear as slightly thickened walls between the reticulations. Often the two bifurcated ridges in the middle are very faint. On the other hand a small ridge may appear between these ridges and the two ventral ridges.

Dimensions (mm.):
L, 0.64; H, 0.34; W, 0.30.

This species resembles in a way *Cythereis walpolei* v. d. Bold (1946, p. 93, pl. 12, fig. 6), but in that species the median ridge is undivided in the center and the anterior end is more broadly rounded. *Cythereis variabilocostata* has been found abundantly everywhere in the La Rosa.

Type locality.—Loc. 11. Type specimens in H. V. Howe collection No. 4025.

Genus PTERYGOCYTHEREIS Blake 1933

PTERYGOCYTHEREIS AMERICANA (Ulrich & Bassler)

Cythereis cornuta (Roemer), var. *americana*

ULRICH and BASSLER, 1904, Maryland Geol. Surv., Miocene, p. 122, pl. 37, fig. 29–33.
? non Cythereis (Pterygocythereis) cornuta, var. *americana* (Ulrich and Bassler), HOWE and grad. stud., 1935, Florida Dept. Cons. Geol. Bull. 13, pl. 26, pl. 2, fig. 19, 21, 24; pl. 4, fig. 24.
? non Cythereis (Pterygocythereis) cornuta, var. *americana* (Ulrich and Bassler), V. D. BOLD, 1946, Contr. Study Ostr., p. 100, pl. 10, fig. 17.

The Venezuelan species is exactly like the *Pterygocythereis* present in a slide from the Maryland Miocene received from Dr. Howe. Specimens from the Chipola lower Miocene of Florida are slightly more slender, but otherwise also similar. As in the figures by Ulrich and Bassler (1904) it possesses a fluted crest on the dorsal margin, divided into two halves, and a slightly flattened spine-like projection at the posterior cardinal angle. In many specimens in the La Rosa formation these crests along the dorsal margin and at the alae have been worn off, leaving rows of nodules. The species called *Cythereis (Pterygocythereis) cornuta* var. *americana* (Ulrich & Bassler) by Howe & grad. stud. (1935) and v. d. Bold (1946) has a short curved dorsal ridge without any sign of nodes or perforations; moreover it has no projection at the posterior cardinal angle. According to a range chart by Hendee Smith the first species is restricted to the Chipola. The other should range from the Chipola to and including the Arca zone of the Choctawhatchee. An almost exactly similar species, which may be identical, has been found in the Chickassawhay. In the La Rosa only the first of the two species has been found, whereas the present author found only the second species in the Miocene of Cuba and Guatemala.

Pterygocythereis americana (Ulrich & Bassler) appears to be confined to the Lower La Rosa. It has not been found in the subsurface La Rosa of the Bolivar coast.

Genus LEGUMINOCYTHEREIS Howe 1936

LEGUMINOCYTHEREIS sp.

Plate 19, figure 4

One right valve of a species of *Leguminocythereis* has been found in the La Rosa formation. It has been figured only to record the genus from Venezuela and because there is a slight difference in hingement from the original description of the genus (Howe & Law, 1936, p. 61).

Hinge.—Anterior blunt tooth with adjacent deep, ovate socket, which joins a deep, slightly crenulate groove. The groove which is narrowest and shallowest in the middle ends in front of a large, blunt, slightly outwardly-bent tooth. Howe indicates a smooth groove in his description.

Dimensions (mm.):

L, 0.92; H, 0.48.

Specimen in H. V. Howe collection No. 4026.

Genus BUNTONIA Howe 1935

BUNTONIA TAMARENSIS van den Bold, n. sp.

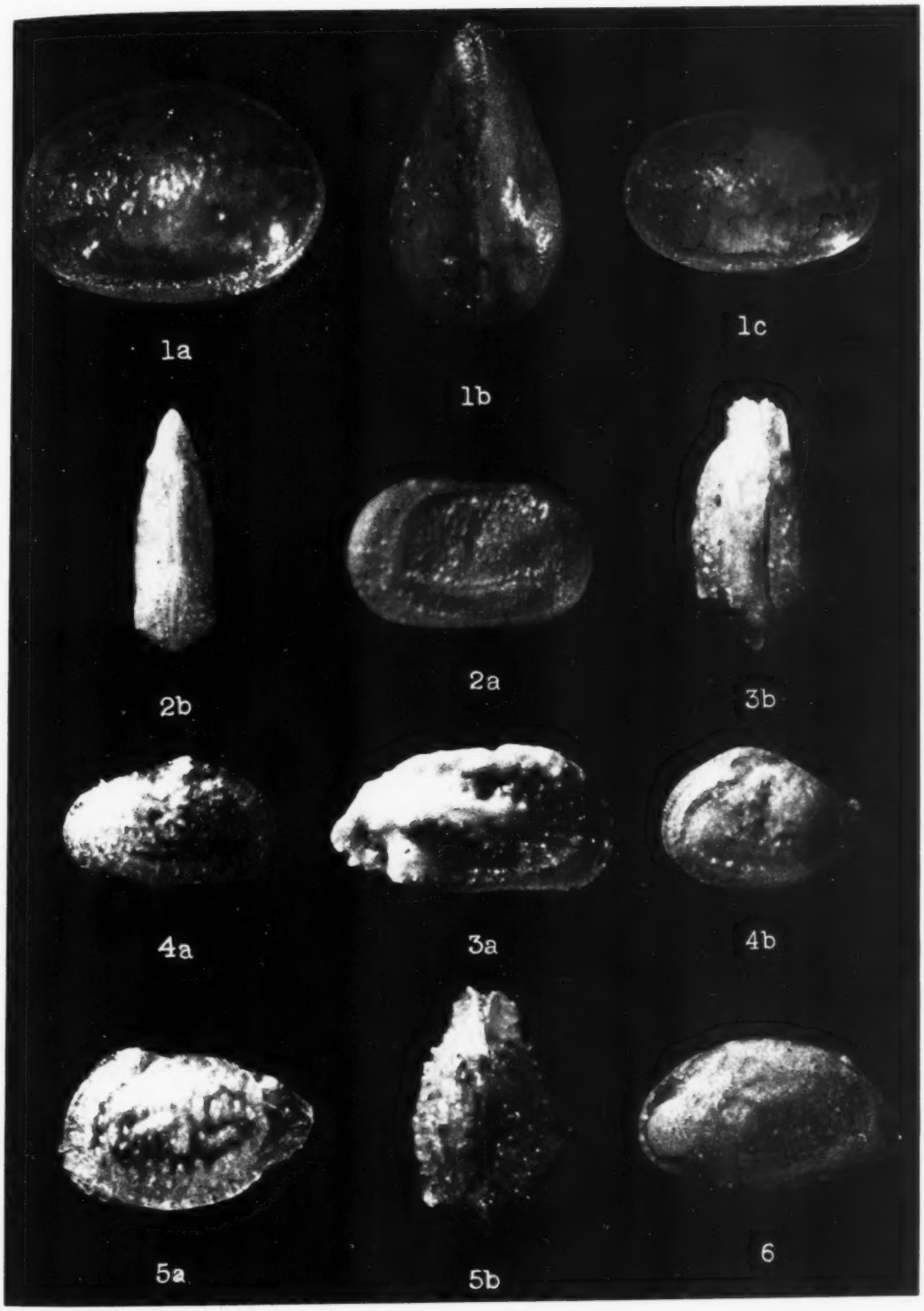
Plate 18, figures 4a, b; text figure 2

Carapace pearshaped, highest at its anterior end. Anterior end obliquely rounded (more so in the left valve than in the right), dorsal margin straight or nearly straight, except for the strongly produced posterior cardinal angle in the left valve. Ventral margin gently convex, converging posteriorly to the dorsal margin. Posterior end truncate or very broadly rounded below the posterior cardinal angle in the left valve, about evenly rounded in the right. Ornamentation consists of a strong anterior marginal ridge, continuing parallel to the ventral margin, but obscured by a ventral ridge, which rises in the anteroventral part of the carapace.

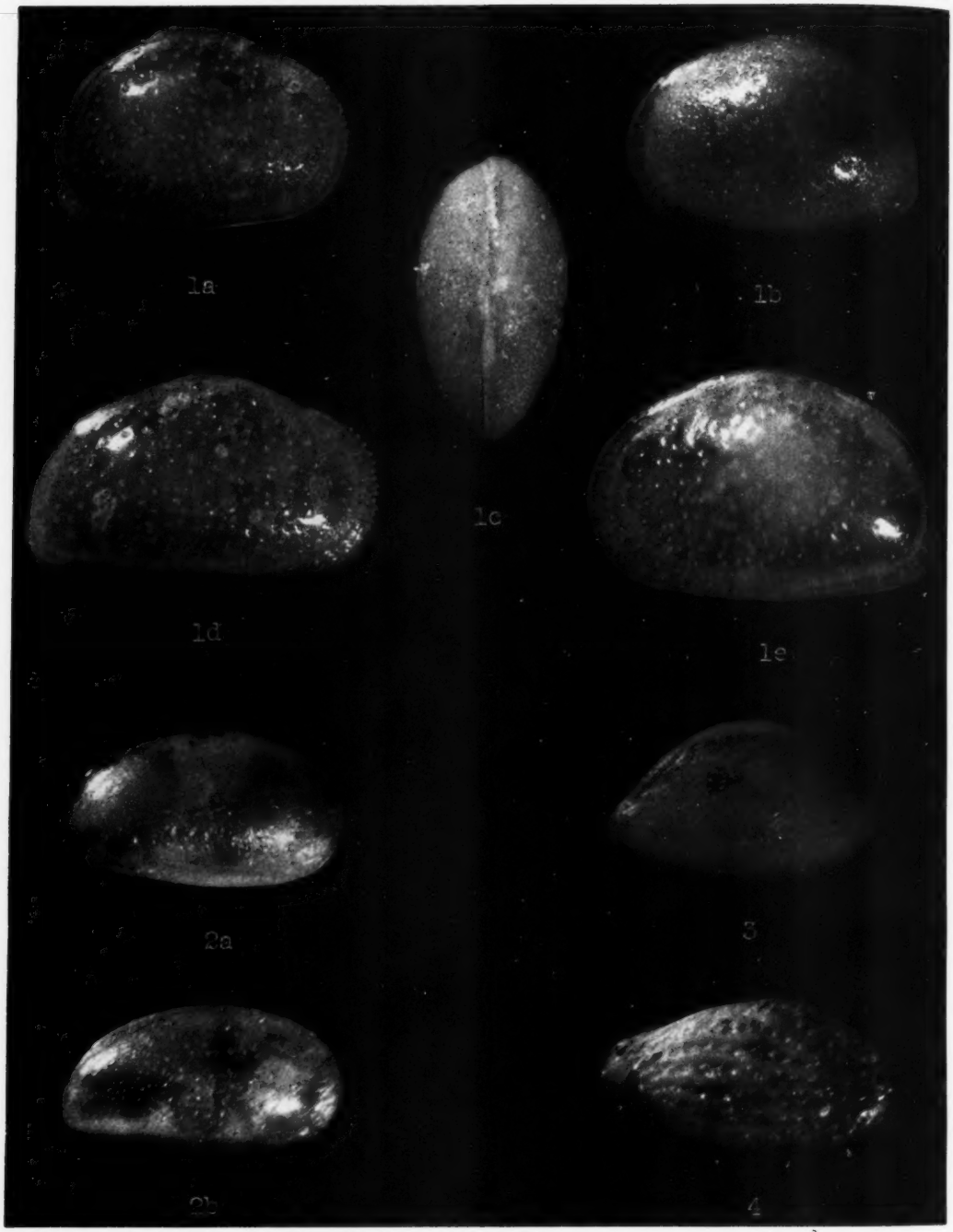
EXAPLANATION OF PLATE 18

All figures ×64

FIGS. *1a–c—Cytherella* sp. *1a*, Left valve, female; *1b*, Dorsal view, female; *1c*, left valve, male. (p. 80)
2a, b—Cytherelloides olayaensis van den Bold, n. sp. *2a*, Left valve; *2b*, Dorsal view. (p. 80)
3a, b—Cythereis variabilocostata van den Bold, n. sp. *3a*, Exterior of right valve; *3b*, Dorsal view. (p. 83)
4a, b—Buntonia tamarensis van den Bold, n. sp. *4a*, Exterior of right valve; *4b*, exterior of left valve. (p. 84)
5a, b—?Cativella crassa van den Bold, n. sp. *5a*, Exterior of left valve; *5b*, Dorsal view. (p. 85)
6—Pellucistoma kendengensis (Kingma). Exterior of left valve. (p. 86)



van den Bold, Venezuelan Miocene Ostracoda



van den Bold, Venezuelan Miocene Ostracoda

Posterior portion of the valves ornamented by several faint ridges which converge posteriorly. The outer ones are almost parallel to the posterior margin, the middle ones longitudinal. There is a faint but distinct vertical sulcus just behind and below the anterior cardinal angle. Left valve overlapping strongly in anterior part of dorsal margin and at posterior cardinal angle. Greatest width slightly behind the middle at the ventral ridge.

Interior typical for *Buntonia* (Howe, 1947).

Dimensions (mm.):

L, 0.48; H, 0.32; W, 0.26.

No species of *Buntonia* have been described from the Miocene. The Oligocene species *Buntonia huneri* (Howe and Law) (*Pyricythereis huneri* Howe and Law, 1936, p. 66, pl. 4, fig. 16; pl. 5, fig. 19–21) is rather similar in ornamentation, but distinctly more elongate.

This species occurs occasionally in the La Rosa of the Bolivar coast subsurface.

Type locality.—Loc. 11. Type specimens in H. V. Howe collection No. 4027.

Genus CATIVELLA Coryell and Fields 1937

CATIVELLA NAVIS Coryell and Fields

Cativella navis CORYELL and FIELDS, 1937, Am. Mus. Novitates, 956, p. 9, fig. 9.

Cativella navis Coryell and Fields, v. d. BOLD, 1946, Contr. Study Ostr., p. 104, pl. 12, fig. 11.

This species occurs in many La Rosa samples.

CATIVELLA? CRASSA van den Bold, n. sp.

Plate 18, figures 5a, b

Carapace ovate, highest at anterior cardinal angle, widest behind the middle in the ventral portion. Eye tubercle well developed. Anterior end obliquely rounded, bearing broad, blunt spines, which are only conspicuous in the lower half, and a marginal ridge, which is broken up into spines in the upper half, and continues parallel to the ventral margin. Here also it has the tendency to divide into spines. Ventral margin strongly convex, curving upward in the posterior end, where it bears some spines. Posterior end compressed, concave above. Dorsal margin straight, partially obscured by a curved dorsal ridge, which also has the tendency to break up into spines or nodules. Ornamentation consists of longitudinal rows of nodules.

Line of concrescence and inner margin coincide. Marginal area moderately broad, pore-canals numerous. Hinge similar to *Cythereis*.

Dimensions (mm.):

L, 0.57; H, 0.35; W, 0.32.

In this species the fluted crests of *Cativella navis* have been replaced by rows of nodules and spines. The shape suggests this species to belong to *Cativella*, though the ornamentation is different. *Cativella? pustulosa* v. d. Bold (1946, p. 105, pl. 9, fig. 22) is the only resembling species. It is, however, easily distinguished by its pattern of vertical ridges and nodules and its more elongate shape. This species is common in many wells of the Bolivar coast.

Type locality.—Loc. 3. Type specimen in H. V. Howe collection No. 4028.

Genus BASSLERITES Howe 1937

BASSLERITES MIOCENICUS (Howe)

Basslerella miocenica HOWE, Howe and grad. stud., 1937, Florida Dept. Cons. Geol. Bull. 13, p. 36, pl. 1, fig. 19, 24–26.

Basslerites miocenicus (Howe), CORYELL and FIELDS, 1937, Am. Mus. Novitates, 956, p. 12, fig. 5.

Basslerites miocenicus (Howe), v. d. BOLD, 1946, Contr. Study Ostr., p. 106 (not pl. 12, fig. 5).

The species described by the author (1946, p. 106) from the Miocene of Guatemala (W48, T103) is *Basslerites miocenicus*

EXAPLANATION OF PLATE 19

All figures ×43

FIGS. *1a–e*—*Haplocytheridea curta* van den Bold, n. sp. *1a*, Exterior of right valve, female; *1b*, Exterior of left valve, female; *1c*, Dorsal view, female, with posterior end upward; *1d*, Exterior of right valve, male; *1e*, Exterior of left valve, male. (p. 81)

2a, b—*Haplocytheridea larosaensis* van den Bold, n. sp. *2a*, Right valve, female; *2b*, Right valve, male. (p. 81)

3—*Bairdia* sp. Right valve. (p. 80)

4—*Leguminocythereis* sp. Right valve exterior. (p. 84)

(Howe). The specimens described under the same name from the localities H67 (Cuba) and T99 (Guatemala) belong to *Basslerites giganticus* Edwards (1944, p. 521, pl. 87, fig. 19–23).

Basslerites miocenicus (Howe) is common throughout the La Rosa.

Genus FAVELLA Coryell and Fields, 1937
FAVELLA RUGIPUNCTATA (Ulrich and Bassler)

Cythere rugipunctata ULRICH and BASSLER, 1904, Maryland Geol. Surv., Miocene, p. 118, pl. 38, fig. 16, 17.
Cythereis rugipunctata (Ulrich and Bassler), HOWE & grad. stud., 1935, Florida Dept. Cons. Geol. Bull. 13, p. 23, pl. 1, fig. 18, 20–22; pl. 4, fig. 22, 23.
Favella rugipunctata (Ulrich and Bassler), EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 524, pl. 88, fig. 5, 6.
Favella rugipunctata (Ulrich and Bassler), V. D. BOLD, 1946, Contr. Study Ostr., p. 100, pl. 10, fig. 3.

This species is common throughout the La Rosa.

Genus CYTHEROMORPHA Hirschmann, 1901
CYTHEROMORPHA WARNERI Howe and Spurgeon

Cytheromorpha warneri HOWE and SPURGEON, Howe and grad. stud., 1935, Florida Dept. Cons. Geol. Bull. 13, p. 11, pl. 2, fig. 5, 8, 9; pl. 4, fig. 4.
Cytheromorpha warneri Howe & Spurgeon, V. D. BOLD, 1946, Contr. Study Ostr., p. 105.

This species is common throughout the La Rosa formation. It is slightly smaller and ornamented with a somewhat finer reticulate pattern than otherwise similar specimens from the Shoal River Miocene of Florida.

Genus LOXOCONCHA Sars, 1865
LOXOCONCHA ANTILLEA v. d. Bold

Loxoconcha antillea V. D. BOLD, 1946, Contr. Study Ostr., p. 110, pl. 15, fig. 3.

This species occurs scattered in the La Rosa formation in both subsurface and surface samples.

LOXOCONCHA RETICULARIS Edwards

Loxoconcha reticularis EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 527, pl. 88, fig. 26, 27.

Occurrence: rare in all parts of the La Rosa formation.

Genus CYTHEROPTERON Sars 1865
CYTHEROPTERON SUBRETICULATUM v. d. Bold

? Cytheropteron subreticulatum V. D. BOLD, 1946, Contr. Study Ostr., p. 113, pl. 14, fig. 6.

This species from the Miocene of Cuba has been found subsequently in the Arca zone of the Choctawhatchee (middle Miocene) and the Caloosahatchee (Pliocene) of Florida in samples from H. V. Howe and in Hendee Smith's type collection. In Venezuela it has been found in some of the wells, but not in surface samples.

Genus PELLUCISTOMA Coryell and Fields, 1937
PELLUCISTOMA MAGNIVENTRA Edwards

Pellucistoma magniventra EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 528, pl. 88, fig. 33–35.

The species occurs rather regularly throughout the La Rosa.

PELLUCISTOMA KENDENGENSIS (Kingma)
Plate 18, figure 6; text figure 3

Javanella kendengensis KINGMA, 1948, Contribution to the knowledge of the Young-Caenozoic Ostracoda of the Malayan region, p. 89, pl. 10, fig. 6.

Carapace elongate, more or less bairdioid in shape. Surface finely punctate. Anterior end obliquely rounded, dorsal margin short and straight, ventral margin sinuate, parallel. Posterior end a subventral caudal process, the posterior margin above is concave. Greatest width in the middle.

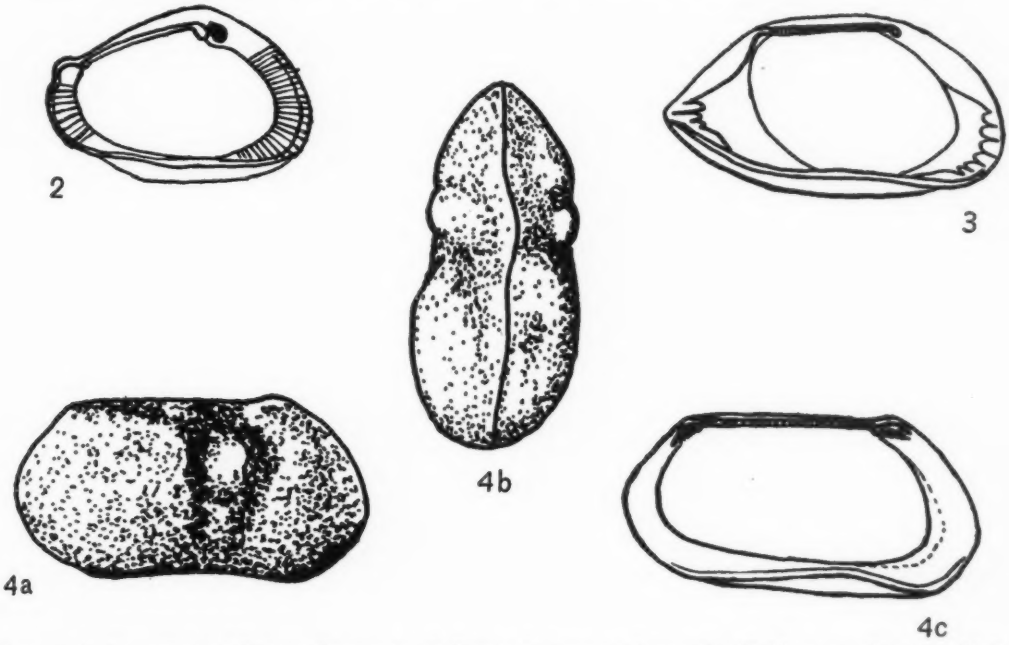
Hinge in the left valve consists of a finely serrate bar with a very small, knoblike tooth at its anterior end. Posterior to the bar is an almost imperceptible socket. In the right valve an imperfectly developed anterior socket is formed by a tooth-like extension of the dorsal margin. A faintly crenulate groove in the dorsal margin is bordered dorsally by a narrow bar, which is slightly thicker at its posterior end and obviously fits into the small socket at the end of the bar in the left valve. Calcified portion of the inner lamella broad at the ends, where the line of concrescence forms a loop-like curve towards the outer margin. Radial pore-canals are few, short and straight and widened at their bases.

Dimensions (mm.):

L, 0.64; H, 0.34; W, 0.25.

Kingma (1948) described this species from

the upper Pliocene of Java, Netherlands East Indies. He believed it to be different from other genera and therefore created the new genus *Javanella* with this species as genotype. The Venezuelan species seems to be exactly similar, as far as can be judged by comparison of figures, especially in the position of the posterior end, the arrangement of pore-canals and to some extent also of the hinge. The La Rosa specimens are distinctly related to *Pellucistoma magniventra* Edwards, though the differences are conspicuous. Therefore the author is convinced that the new species belongs to the genus *Pellucistoma*.



FIGS. 2–4—Venezuelan Miocene Ostracoda. *2*, ***Buntonia tamarensis*** van den Bold, n. sp., interior of lef valve, ×64. *3*, ***Pellucistoma kendengensis*** (Kingma), interior of left valve ×64. *4a–c*, ***?Limnocyther venezolana*** van den Bold, n. sp., ×100; *a*, right valve; *b*, dorsal view; *c*, interior of left valve.

It occurs in surface samples of both Upper and Lower La Rosa and in almost every well sample studied from the la Rosa interval.

Specimens in H. V. Howe collection No. 4029.

Genus LIMNOCYTHERE Brady, 1868

LIMNOCYTHERE? VENEZUELANA
van den Bold, n. sp.
Text figure 4a–c

Carapace elongate rectangular, slightly higher in front. Anterior end broadly rounded, posterior end narrowly rounded, very slightly concave above. Ventral margin slightly sinuate, dorsal margin very slightly convex and parallel. Ornamentation consists of a strong anterior marginal ridge and a deep subvertical and subdorsal sulcus in the anterior half of the carapace. This sulcus is divided into two parts by an oval node, slightly elongate in vertical direction. Surface deeply punctate. Greatest width in posterior half. Dorsal view very characteristic because of the anterior lobe and sulcus.

Hinge in the left valve consists of crenulate sockets with a crenulate bar in between. At the anterior end of the bar a very small, knob-like tooth. Hingeline straight, but curving slightly over the sockets. Calcified portion of the inner lamella moderately broad. Line of concrescence and inner margin do not coincide at the anterior end

Dimensions (mm.):

L, 0.47; H, 0.24; W, 0.21.

This species is very close to *Limnocythere? williamsi* Swain (1947, p. 527, pl. 77, fig. 30–33). In both species the inner margin and line of concrescence do not coincide in the anterior end. The hinge, however,

is slightly different. Müller (1900, pl. 20, fig. 8) indicates for the hinge in the left valve a crenulate ridge with a crenulate socket posterior to it and a possibly crenulate or irregular socket anterior to it. Line of concrescence and inner margin coincide throughout. As hinge and marginal area in the Venezuelan species are slightly different the generic assignment is questionable.

This species has been found occasionally in the La Rosa, in one surface sample and in some well samples. As all relative forms occur in fresh- or brackish water environment, this species is likely to have been deposited in fresh- or brackish water beds. However, the La Rosa is a strictly marine formation in which no brackish intercalations are known. This species may be derived from Oligocene deposits.

Type locality.—Loc. 12. Type specimens in H. V. Howe collection No. 4019.

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ORIGIN OF THE PELECYPOD FAMILY GLYCYMERIDAE

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ABSTRACT—The Glycymeridae evolved from a cucullaeid stock probably during late Jurassic time. A study of the morphologic characters of both families proves that they are remarkably similar, particularly when Cretaceous species are considered. The chronogenetic and geographic evidence confirms the data shown by the morphologic characters. If only mature specimens are examined, the hinge teeth of the two families appear unrelated. A young cucullaeid, however, goes through a stage of tooth development which is like that of the Glycymeridae.

INTRODUCTION

THE phylogenetic study presented here is a part of a thesis completed at Stanford University in 1947. The writer is particularly indebted to Lieutenant Colonel Hubert G. Schenck of Tokyo, Japan, but formerly at Stanford University, who lent his specimens and notes on the Glycymeridae.

The main purpose of research of this type is to improve the present classification of the prionodont pelecypods by putting it on a more secure foundation. The term prionodont is used in preference to taxodont because the former term excludes the Nuculidae and Nuculanidae. MacNeil (1937, pp. 457, 458; 1938, pp. 1, 2) included in his suborder Prionodonta the phylogenetically related superfamilies Cyrtodontacea, Parallelodontacea, Glycymeracea, and Arcacea. Pelseneer, Douvillé, and others have pointed out the fact that the prionodonts are not closely related to the true taxodonts such as *Nucula*, *Nuculana*, and *Yoldia*. Certain basic precepts must be considered for a correct solution of the problem. Comparison of a genus or a family with other closely related genera or families must be based on a summation of all available morphologic characters and should be verified by chronogenetic and geographic evidence.

The earliest occurring species should be the most closely studied because there appears to be a natural evolutionary drift away from the ancestral or primitive characters as the group becomes better adapted to its environment, or perhaps changes with a changing environment. Change will occur in the ancestral group as well, so that related genera or families may show little or no similarity if they both have been in existence for many millions of years.

The geologic history of the Glycymeridae is comparatively complete; and specimens, figures, and descriptions of the early Cretaceous species are, fortunately, adequate to solve the problem of the origin of the family.

Many paleontologists and conchologists have made comparisons between the morphology of the Glycymeridae and that of other prionodont pelecypods, and, on this basis, a few have made conjectures as to the probable origin of the family.

As early as 1887 Fischer (p. 978) stated that *Trigonarca* probably belonged to the genus *Pectunculus*. *Pectunculus, sensu lato,* is the exact equivalent of *Glycymeris, sensu lato,* of most recent workers in paleontology and conchology.

Gillet (1924, p. 18) noted the fact that the hinge of *Trigonarca* is intermediate between that of the rest of the Arcidae and that of the genus *Pectunculus*. On the same page she stated that the hinge of *Pseudocucullaea* is like *Idonearca*, and that the exterior of the shell is like that of *Pectunculus*. Gillet also noted the resemblance of form of the early Cretaceous species *Idonearca* (*Dicranodonta*) *obliqua* (Keeping) to *Pectunculus*. *Pectunculus obliquus* Keeping, 1883, has an outline and hinge resembling species which belong to the genus *Lopatinia* Schmidt, 1872. Finlay (1926, p. 525) has changed the species name to *keepingi*, because *obliquus* is a homonym.

Schenck (1936, p. 414) claimed that the Limopsidae may be taken as the hypothetical radicle of the Glycymeridae.

From a somewhat different standpoint,

Douvillé (1912, p. 432) made the following assertion:

> De même, les Arches à fixation pédieuse et à coquille inéquilatérale, deviennent symétriques lorsqu'elles reprennent une vie active (*Pectunculus*).

Davies (1933, p. 325, fig. 2) followed Douvillé and showed in a figure that *Glycymeris*, which is free, arose from an *Arca*, which had a temporary byssal attachment.

When the early Cretaceous species of the Glycymeridae are compared with Cenozoic ones, the greater symmetry of the latter species is apparent and may be attributed to the free or active life of the members of the family if they had originated from ancestors, which were temporarily attached by a byssus, as Douvillé and Davies believed.

From this brief review of previous work it may at once be noted that only casual observations have so far been made in comparing the Glycymeridae with other prionodont groups. It is, therefore, necessary to have a complete review of the morphologic characters with a proper evaluation of each one in order to arrive at a correct conclusion.

REVIEW OF MORPHOLOGIC CHARACTERS

In the following discussion on morphologic characters the writer realizes that each one discussed probably consists of many unit characters or biocharacters of Swinnerton (1930, p. 389). It is not practical to attempt such detail in this type of study because numerous specimens are needed.

Only chronologically primitive characters of the Glycymeridae will be discussed in detail. These will be compared with the same morphologic features of other prionodont groups. The Cretaceous species mentioned herein will be most nearly allocated to the subgenus *Glycymerita* Finlay and Marwick, 1937.

Form of the valves.—The valves of the Glycymeridae are always equal, with no gape for the foot, byssus, or siphons. Some other related prionodont genera which are equivalve and have no gape are *Limopsis*, *Noetia*, *Trigonarca*, and at least the adult specimens of *Larkinia* and *Anadara*.

Most of the Anadarinae among the Arcidae and apparently most of the Cucullaeidae have shells which have no gape, but they are discordant, the left valve always being the larger of the two. The right valve fits into the left valve, the left overlapping the right along the ventral margin.

Often associated with discordant valves is a marked difference in ornamentation of the two valves, the left valve, in most cases, being the more strongly ornate. Difference in ornamentation has been noticed by Cox (1937, p. 195, pls. 15, 16) in Jurassic species of *Indogrammatodon*, and the same author more recently (1940, pp. 37, 41, 47, 56; pls. 2–4) has observed differences in ornamentation between the two valves in Jurassic species of *Grammatodon*, *Indogrammatodon*, and *Megacucullaea*. Vokes (1946, pp. 151–153) stated that a difference in ornamentation between the right and left valves could be especially well seen in immature specimens of the genus *Arcullaea* which is found in the Lower Cretaceous rocks of Lebanon.

The outline of the valves of the earliest glycymerid species is subquadrate to subcircular with the length slightly greater than the height (pl. 22, fig. 4). The ratio of convexity to height is greater in the early Cretaceous species than in most Tertiary and Recent species which have an average convexity ratio of 0.60, while most Cretaceous species have a convexity ratio greater than 0.60, sometimes as great as 0.90. The posterior margin of the early Cretaceous species is always truncated, and sometimes the anterior border is also slightly truncated, giving the shell a subquadrate outline. Often in conjunction with the posterior truncation, a constriction of the valves running from the umbo to the posterior margin is present. This constriction marks an area that is flattened, and in extreme cases is slightly sunken to form a heart-shaped depression (pl. 22, fig. 16).

The primitive glycymerids have a general outline similar to many species of the Cucullaeidae. This resemblance of outline was noticed by Marwick (1923, p. 64). In fact, several species of Cretaceous glycymerids were first placed in the genus *Cucullaea* before the hinge was observed. The Cretaceous genera *Dicranodonta*, *Protarca*, and *Perularca* also have an outline similar to species of *Glycymeris*. For striking evidence of the similarity of valve outline of the Glycymeridae and the Cucullaeidae, part of plate 2, taken from Finlay and Marwick, 1937, is reproduced here (pl. 20, figs. 1–4).

Position of the beaks.—In primitive glycymerids the beaks are always orthogyrate and located a little posterior to the center of the dorsal margin (pl. 21, fig. 12). Other prionodont groups having orthogyrate beaks located at approximately the center of the dorsal border are the Limopsidae (pl. 22, fig. 2), *Peruarca* (pl. 20, fig. 5), *Pseudocucullaea* (pl. 21, fig. 2), *Dicranodonta* (pl. 20, fig. 7), and *Idonearca* (pl. 21, fig. 9).

species of the Glycymeridae have what Reinhart considers a highly inclined cardinal area (fig. 1a, here figured, pl. 21, fig. 11). The inclination of the cardinal area appears to be correlated at least partially with convexity. Thus, the most convex glycymerids, mainly Cretaceous species, have the least inclined cardinal area. Many of the Noetiidae, Anadarinae, and Cucullaeidae have a cardinal area which has about the same inclina-

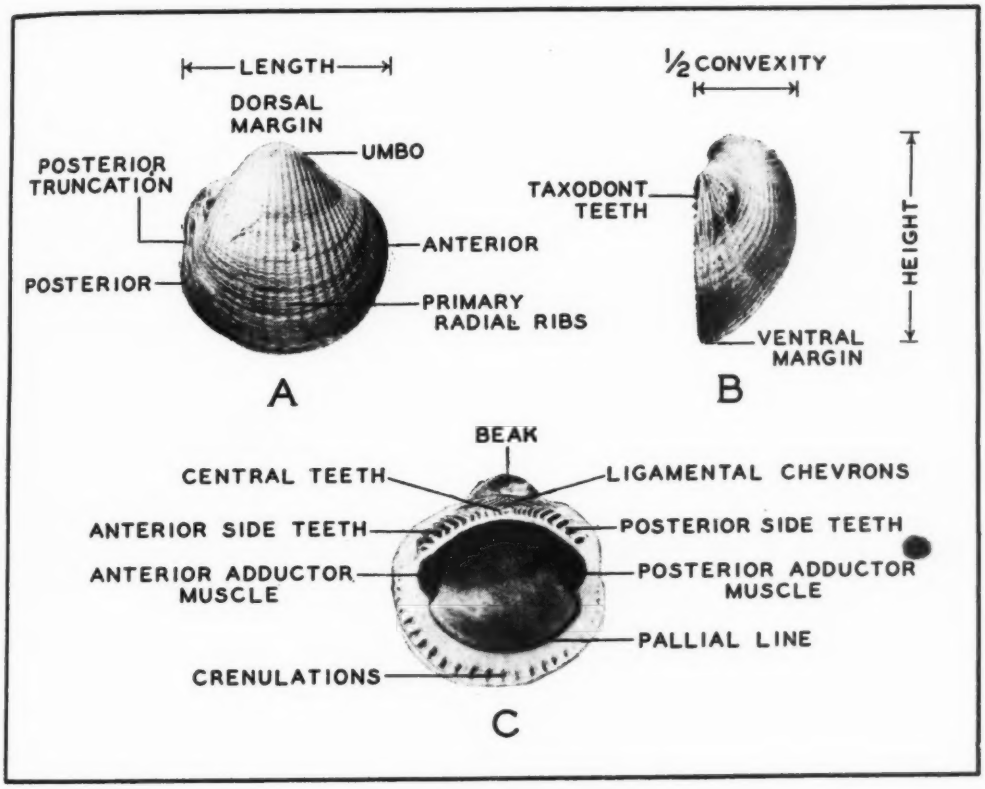


FIG. *1a–c*.—Morphologic chart of a glycymerid, *Glycymeris* (*Glycymerita*) *veatchii*; *a*, exterior view; *b*, posterior view; *c*, interior view. Hypotype in Stanford University Paleontology Type Collection

Inclination of the cardinal area.—Reinhart (1943, fig. 1, p. 7) has shown that the flat area between the beaks, a part or all of which is occupied by the ligament, may vary as to its inclination (flatness or steepness) in various arcids. Some of the Cretaceous species of glycymerids show curved or U-shaped cardinal areas resembling fig. 1c shown by Reinhart of *Anadara* (here figured, pl. 21, fig. 14). Most of the Tertiary and Recent

tion as that of some of the Cretaceous Glycymeridae.

Position of the ligamental area.—The amphidetic ligamental area occupies the central part of the dorsal margin. In *Glycymerita* the beaks are situated opposite the center of the ligamental area or slightly posterior to the center (text fig. 1c). A similar position of the ligament in relation to the beaks is seen in *Dicranodonta* (pl. 20, fig. 7),

Idonearca (pl. 21, fig. 9), *Pseudocucullaea* (pl. 21, fig. 2), and *Peruarca* (pl. 20, fig. 5).

The ligament.—The ligament of the most primitive glycymerids is duplivincular (see Newell, 1942, pp. 13, 29). The chevron-shaped grooves are strongly marked, and each limb is about equal in size; occasionally the posterior limb is slightly shorter than the anterior (text fig. 1c). Other prionodont groups having a similar duplivincular ligament are *Protarca* (pl. 21, fig. 10), *Trigonarca* (pl. 21, fig. 13), *Cucullaea* (pl. 20, fig. 1), *Dicranodonta* (pl. 20, fig. 7), *Idonearca* (pl. 21, fig. 9), *Pseudocucullaea* (pl. 21, fig. 2), and the Anadarinae.

Nature of the shell.—A cursory examination was sufficient to ascertain that the shell was always porcellaneous in the Glycymeridae, and a detailed study of the shell for additional information was not made. Bøggild (1930, p. 277) has examined representatives of the Arcidae, Limopsidae, Glycymeridae, and Cucullaeidae and has found the shell structure to be very much alike in all these families.

Ornamentation of the shell.—The Glycymeridae have similar ornamentation on both valves. Concentric ornamentation in *Glycymerita* is feebly developed or absent. The radial ribs are strongly developed (raised), however, and sometimes have radial striations developed upon them.

In *Pectunculus marullensis* Leymerie[1] from the Lower Cretaceous of France the radial ornamentation consists of well-marked ribs separated by smaller ribs. At the center of the shell a large and a small rib usually alternate (pl. 22, figs. 5, 8), but at either end the ribs are of equal size. This is soon superseded by the type of ornamentation most commonly seen in early Cretaceous glycymerids where the primary ribs are all of equal size and secondarily striated (pl. 22, fig. 1). These striations are well-developed on *Glycymeris reevei*, and an enlarged portion of the exterior is figured here (pl. 22, fig. 3).

Several other prionodont genera have this same type of ornamentation. Some species of the Anadarinae (pl. 21, fig. 1) and a few species of the Noetiidae have strong radial ribs which show striations developed on the ribs. *Dicranodonta* (pl. 20, fig. 6), a subgenus of *Idonearca* from the Lower Cretaceous of Europe, has strong, unequal, radial ribs, one strong rib being separated by several weaker ones. The ornamentation seen on *Dicranodonta* is similar to that of *Pectunculus marullensis* (pl. 22, figs. 5, 8). Species of *Megacucullaea* and *Indogrammatodon* from the Jurassic of India have an ornamentation most like that of the primitive glycymerids (see Cox, 1940, pls. 3, 4). *Cucullaea vagans* Keeping (pl. 22, figs. 6, 7, 11) from the Lower Cretaceous of England has an outline, ribs, and crenulations on the inner ventral border like the Glycymeridae. Many other examples of Mesozoic Cucullaeidae could be given which have ribbing similar to the Glycymeridae.

Crenulations on the interior ventral border.—The crenulations on the interior ventral

[1] Despite what Gillet (1924, p. 20) stated to the contrary, there appears to be a difference in the ornamentation between the French and English specimens of *Pectunculus marullensis* so that they are probably not the same species.

EXPLANATION OF PLATE 20

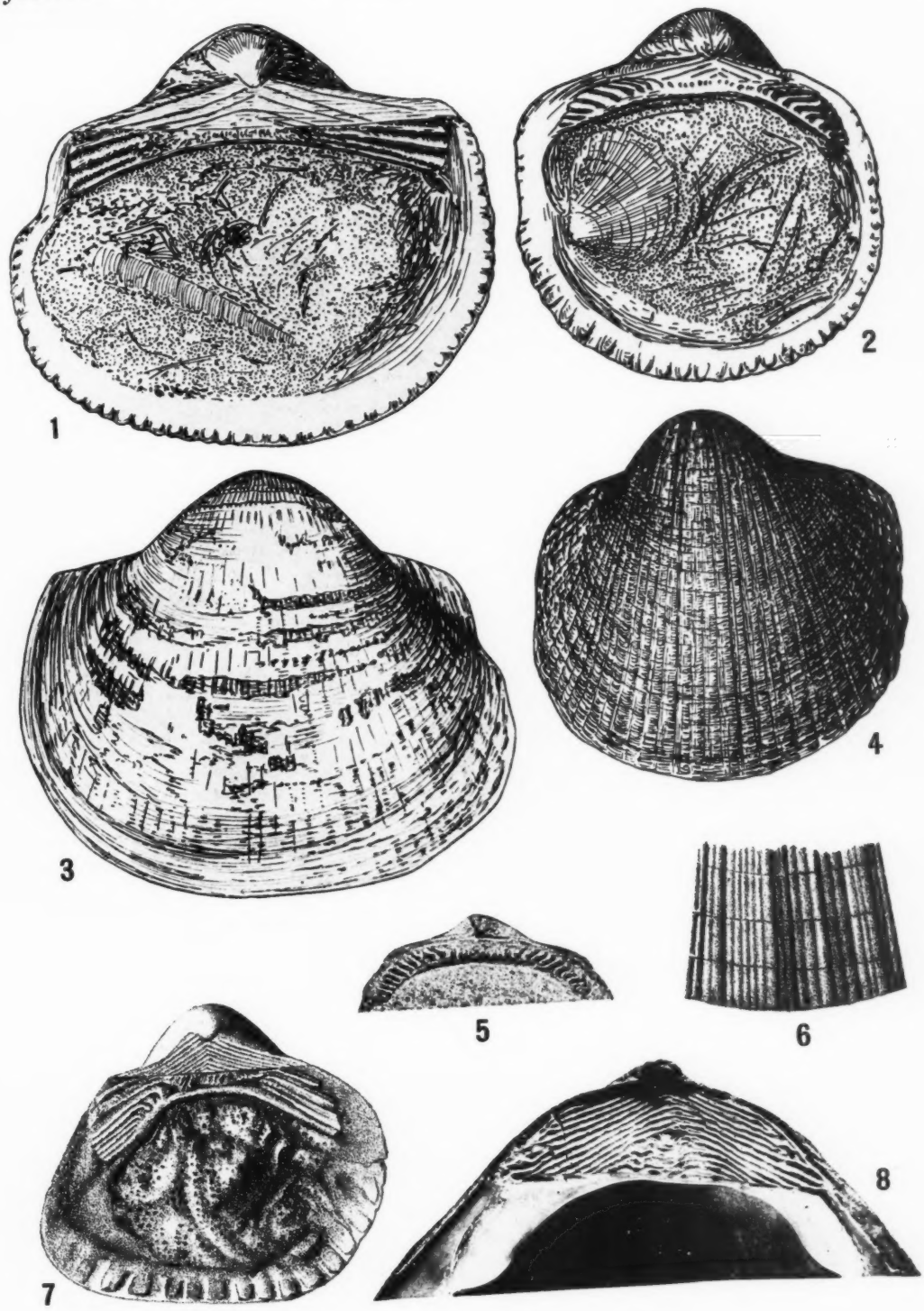
FIGS. *1, 3*—*Cucullaea* (*Cucullona*) *inarata* Finlay and Marwick. Genotype of *Cucullona*. Wangaloan, Danian, New Zealand. *1*, Interior view, ×1; *3*, Exterior view, ×1. (Copied from Finlay and Marwick, 1937, pl. 2, figs. 3, 4. Paratype in New Zealand Geological Survey Collection). (p. 90)

2, 4—*Glycymeris* (*Glycymerita*) *concava* Marshall. Genotype of *Glycymerita*. Wangaloan, Danian, New Zealand. *2*, Interior view, ×1; *4*, Exterior view, ×1. (Copied from Finlay and Marwick, 1937, pl. 2, figs. 1, 6. Specimen in New Zealand Geological Survey Collection.) (p. 90)

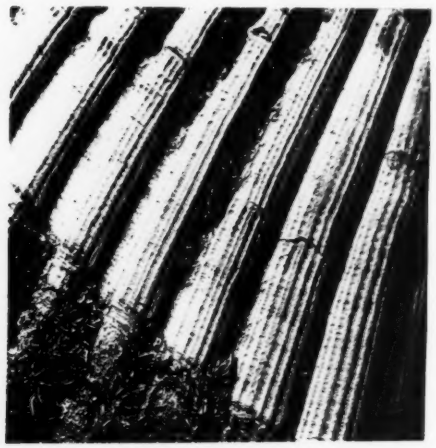
5—*Peruarca pectunculoides* Olsson. Genotype of *Peruarca*. Upper Cretaceous, Paita, Peru. Figure showing hinge teeth, ×$\frac{4}{3}$. (Copied from Olsson, 1944, pl. 3, fig. 6. Holotype no. 4817 Paleontological Research Institution.) (p. 92)

6, 7—*Cucullaea* (*Dicranodonta*) *donningtonensis* Keeping. Genotype of *Dicranodonta*. Lower Cretaceous, England. *6*, Ornamentation, ×3; *7*, Interior view, left valve, ×1. (Copied from Woods, 1899, pl. 10, figs. 11c, 13. Types in Woodwardian Museum). (p. 92)

8—*Grandaxinaea laticostata* (Quoy and Gaimard). Recent, dredged from Nelson Harbor, New Zealand. Interior view, right valve, gerontic specimen showing hinge plate devoid of teeth, enlarged ligamental area, ×1. Hypotype in Stanford University Paleontology Type Collection.



Nicol, pelecypod family Glycymeridae



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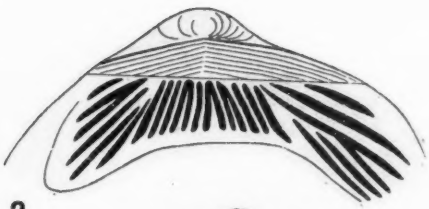

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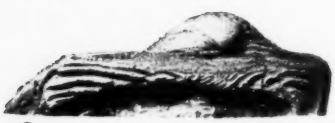

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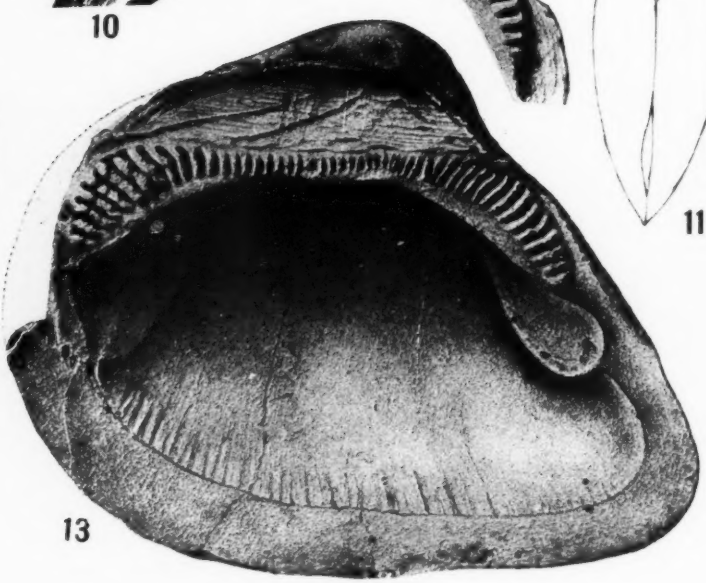

13

14

Nicol, pelecypod family Glycymeridae

border are strongly developed in all species of *Glycymerita* (text fig. 1c) and occur at a position corresponding with the interspaces between the primary radial ribs on the exterior of the shell. The same relationship of crenulations and ornamentation occurs in other prionodont genera. There is, also, an apparent positive correlation between the width and height of the radial ribs and the size of the crenulations. Prionodont groups having crenulations on the interior ventral border are *Dicranodonta* (pl. 20, fig. 7), and a few other Cucullaeidae (pl. 20, fig. 1), the Noetiidae, *Lunarca*, *Larkinia*, *Scapharca*, *Cunearca*, *Anadara*, and a few Limopsidae.

The hinge teeth.—The numerous similar teeth are located on an arched hinge plate just below the ligament. This arrangement and type of dentition is called prionodont. For convenience the teeth may be divided arbitrarily into the central ones, those lying just below the ligament and perpendicular to the dorsal border, and the anterior and posterior side teeth which are present anteriorly and posteriorly respective to the central ones (text fig. 1c). The writer is purposely avoiding the use of the terms cardinal teeth and lateral teeth as used in heterodont pelecypods because the central and side teeth of the Glycymeridae are not homologous in the strictest sense with the cardinals and laterals of the heterodonts (see Bernard, 1898, p. 200).

On all but the smallest specimens of Cretaceous glycymerids, the longer side teeth show a hooked or almost chevron-like shape. The proximal part of the tooth is much shorter than the distal. The same hooked appearance of the side teeth is present in the Cucullaeidae and is well-developed in the Cretaceous species of *Idonearca* (pl. 21, fig. 9). *Dicranodonta* (pl. 20, fig. 7) has this character developed to the highest degree. Chevron-shaped teeth are present in *Protarca* (pl. 21, fig. 10) and *Arcullaea* (pl. 21, fig. 4). Reinhart (1943, p. 9) has called this type of tooth V-shaped and has noticed it in some of the Arcidae.

The largest teeth on the hinge of the Glycymeridae often have striated sides. This

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EXPLANATION OF PLATE 21

FIG. *1*—*Anadara* (*Larkinia*) *multicostata* (Sowerby). Recent, Lower California. Ornamentation, left valve, ×2. Hypotype in Stanford University Paleontology Type Collection. (p. 92)

2—*Pseudocucullaea incisa* Solger. Upper Cretaceous, Cameroons. Right valve showing teeth, ligament, and beak, ×2. (Copied from Solger, 1903, p. 79, fig. 6.) (p. 91)

3—*Pseudocucullaea lens* Solger. Genotype of *Pseudocucullaea*. Upper Cretaceous; Cameroons. Left valve showing hinge teeth and beak. (Copied from Solger, 1903, p. 79, fig. 4b.) (p. 96)

4—*Arcullaea olea* Vokes. Genotype of *Arcullaea*. Aptian, Lower Cretaceous, Lebanon. Interior view, left valve, ×1.4. (Copied from Vokes, 1946, pl. 1, fig. 17. Holotype American Museum Natural History no. 25991:1.) (p. 93)

5–7—*Cucullaea glabra* Parkinson. Upper Cretaceous, England. Figures showing development of hinge teeth, *5*, ×4, *6*, ×2, *7*, ×1½. (Copied from Woods, 1899, pl. 11, figs. 10–12. Types in Woodwardian Museum.) (p. 94)

8—*Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka). Upper Jurassic, British Somaliland. Figure showing hinge teeth, ligament, and beak. (Copied from Cox, 1937, pl. 15, fig. 10 Hypotype L-53574 British Museum Natural History.) (p. 96)

9—*Cucullaea* (*Idonearca*) *capax* Conrad. Genotype of *Idonearca*. Ripley formation, Upper Cretaceous, Mississippi. Interior view, right valve, showing hinge teeth, ligament, and beak, ×1. Hypotype in Stanford University Paleontology Type Collection. (p. 91)

10—*Protarca obliqua* Stephenson. Genotype of *Protarca*. Upper Cretaceous, North Carolina. Figure showing hinge teeth, ligament, and beak of right valve. (Copied from Stephenson, 1923, pl. 19, fig. 3. Holotype cat. no. 31500 U. S. National Museum.) (p. 92)

11—*Barbatia velata* (Sowerby). Recent, Galapagos Islands. Anterior view showing small cardinal angle, ×0.9. (Copied from Reinhart, 1933, text fig. 3a, p. 26. Hypotype 5309 Stanford University Paleontology Type Collection.) (p. 91)

12—*Glycymeris* (*Glycymerita*) *veatchii* (Gabb). Upper Cretaceous, California. Interior view, right valve, ×1. Hypotype in Stanford University Paleontology Type Collection. (p. 91)

13—*Trigonarca maconensis* (Conrad). Genotype of *Trigonarca*. Upper Cretaceous, Georgia. Interior view. (Copied from Stephenson, 1923, pl. 15, fig. 1. U. S. National Museum cat. no. 31488.) (p. 92)

14—*Anadara camuloensis* (Osmont). Pliocene, California. Figure showing U-shaped cardinal angle, ×0.3. (Copied from Reinhart, 1933, text fig. 3c, p. 26). (p. 91)

character is strongly marked in the Cucullaeidae, including *Dicranodonta* and *Pseudocucullaea*, and it is sometimes observed in the Arcidae. Grooved or striated teeth are easily observed in the Trigoniidae and many of the Unionidae.

The most striking evidence of the similarity between the hinge teeth of the Glycymeridae and those of the Cucullaeidae has been presented by Arkell (1930, p. 305, figs. 6–8). These figures show the young stages of the hinge of *Cucullaea glabra* Parkinson from the Upper Cretaceous of England copied from Woods (1899, pl. 11, figs. 10–12) and reproduced here (pl. 21, figs. 5–7). Arkell (p. 305) made the following observation concerning these figures:

> At first there is a series of short, dorsally-divergent, sub-equal teeth, similar to those of *Glycimeris* (*Glycymeris*), *Limopsis*, or *Barbatia*. Later the outer teeth, both posterior and anterior, become elongate and curve outward, so as to run parallel to the hinge margin.

Apparently the Glycymeridae have a hinge which is like the early stages of the Cucullaeidae. If the stages of growth and development of the hinge of *Idonearca* (pl. 21, fig. 9) are represented by the letters ABCDE, the last letter representing the elongation of the side teeth (outer teeth of Arkell), then the development of the hinge teeth of the Glycymeridae (pl. 21, fig. 12) can be represented by the letters ABCD. *Dicranodonta* (pl. 20, fig. 7), on the other hand, appears to have gone one stage farther, with the extreme elongation of the side teeth, so that the development of the hinge can be represented by the letters ABCDEF.

More recently Iredale (1939, p. 250) has observed the similarity of the hinge teeth of a young specimen of Recent *Cucullaea* to the hinge of the arcids and makes the following statements:

> Family value has been given this genus [*Cucullaea*] mainly on account of the hinge teeth, the flanged muscle scar and the antiquity of the group. Yet the hinge can be paralleled among the true Arks, the muscle scar is not flanged in the juvenile while there are some small Arks which show a scar flangeing, and many Ark groups are also well distinguished in early paleontological ages. It may be admitted that on the first finding of very small shells of this group they were regarded as Arks, and only when growth series were sorted out was their identity recognized.

Compare Iredale's plate 2, figure 17b of *Cucullaea labiata petita* (juvenile, showing hinge) with other hinges of arcids on the same plate.

Both *Glycymerita* (pl. 21, fig. 12) and *Idonearca* (pl. 21, fig. 9) have the small central teeth which are perpendicular, or nearly perpendicular to the dorsal border. The main differences are seen in the stronger hinge plate, which is less arched at the dorsal border, and the longer and stronger side teeth of *Idonearca*.

The area of the hinge of the Glycymeridae underwent the following modifications from the cucullaeid ancestor: (1) The dorsal margin became more rounded with a corresponding shortening of the ligamental area. (2) The hinge plate became more arched and weaker or less high (measured from the dorso-ventral direction). (3) With the corresponding arching and weakening of the hinge plate, the side teeth became shorter and arranged in a more regular arc; only the most distal ones became parallel to the dorsal margin.

The adductor muscle scars.—Glycymerids have the posterior adductor scar with a stronger flange or buttress at its anterior side than the anterior adductor scar. The only reason for this difference that the writer can give is that the valves of the ancestral glycymerid had a posterior truncation, as is weakly shown in many Cretaceous species. The raised flange occurs in many prionodont groups which are obese and have a posterior truncation. The Cucullaeidae have a strong flange at the anterior border of the posterior adductor muscle scar, and this character is better developed in this family than in any other prionodont group. Other prionodont groups showing this character are *Noetia* and *Trigonarca*. These two genera are obese and have a posterior truncation.

Internal Anatomy.—An examination of the internal anatomy of the Glycymeridae for the purpose of comparing anatomical features with other prionodont groups was not made. A good general review of the Glycymeridae is given by Pelseneer (1911, pp. 7, 8). Heath (1941, pp. 306–309) has done some careful anatomical work on four species of *Glycymeris* and one species of *Cucullaea*. His conclusion (p. 313) is that the relation of both these genera to the Arcidae is obscure.

CHRONOGENETIC AND GEOGRAPHIC EVIDENCE

The conclusion that the Glycymeridae evolved from the Cucullaeidae, gained by a study of the morphologic characters, must be compared with the evidence presented by chronogenesis and geographic distribution.

The earliest species which clearly belongs to the Glycymeridae is *Pectunculus marullensis* Leymerie, 1842, from the Neocomian (Lower Cretaceous) of France. Gillet (1924, tab. 3, p. 19) places this species at the base of the Cretaceous. No proved Jurassic occurrences of the Glycymeridae have been found by the writer.

The genus *Idonearca* occurs first during early Jurassic time according to Gillet (1924, tab. 3, p. 19) and by the late Jurassic is abundant as to number of species and variety of form. Gillet (1924, pp. 16–18) mentions five different species groups occurring during the early Cretaceous. Of these five groups the most likely ones to have given rise to the ancestral form of the Glycymeridae, according to their morphology, would be her second "groupe" which includes *Idonearca gabrielis* (Deshayes), *I. forbesi* (Pictet and Campiche), *I. moreana* (d'Orbigny), etc. This species group appears first in the early Jurassic and is well represented in the Mediterranean area. Another possibility is Gillet's third "groupe and section," which has recently been named *Megacucullaea* by Rennie, and which has an external form and ribbing similar to the Glycymeridae. *Megacucullaea* is abundant in the strata of late Jurassic age in Africa and India. *Cucullaea vagans* Keeping (here figured, pl. 22, figs. 6, 7, 11) from the Lower Cretaceous of England has many morphologic characters like the Glycymeridae, and it is a species similar to this one, occurring in the Tethys Sea during late Jurassic time, which probably gave rise to the Glycymeridae.

From the standpoints of time of occurrence and geographic location, a member of the Cucullaeidae certainly could have given rise to the Glycymeridae.

CONCLUSIONS

With the accumulated evidence at hand, the writer is certain that the ancestor of the Glycymeridae was a species belonging to the genus *Idonearca* of the family Cucullaeidae. The following modifications of morphologic characters took place in the transition from *Idonearca* to *Glycymerita*.

1. The outline changed from quadrate or subrhomboidal to subquadrate with an arched dorsal margin and a more symmetrically rounded outline. The posterior truncation and constriction became less pronounced, and the convexity became less in *Glycymerita* than in the ancestral cucullaeid.

2. With the rounding of the dorsal border the ligamental area decreased in length in *Glycymerita*, and the hinge plate became more arched and weaker.

3. The central teeth changed little, although they appear to have become shorter in *Glycymerita*. The most pronounced change occurred in the modification of the side teeth. The ancestral cucullaeid had long side teeth arranged almost one above the other, all of them parallel or nearly parallel to the dorsal margin. Usually the distal side teeth of *Idonearca* are slightly divergent ventrally. The side teeth in *Glycymerita* became much shortened and arranged in a converging arc instead of being arranged one above the other. This shortening of the side teeth became necessary because the hinge plate became arched and weaker.

4. The ancestral cucullaeid had strong, raised, radial ribs, possibly unequal in size, and these ribs may have had radial striations superimposed upon them. Crenulations on the interior ventral border were most likely present in the ancestral cucullaeid.

These similarities and changes of morphology, with the exception of the modification of the hinge teeth, can be easily imagined by most paleontologists. Workers who have studied many different prionodont groups, however, know that there is much variation in the number, position, and shape of the hinge teeth even within a closely knit family, as, for example, in the Glycymeridae (see pl. 20, fig. 8; pl. 21, fig. 12; pl. 22, figs. 2, 9, 10, 13–15). In the Arcinae Arkell (1930, pp. 348, 349) noted the stability of shell characters as compared to the more plastic dentition of *Eonavicula* and its descendant, *Arca*. In the heterodont pelecypods the number, position, and shape of the teeth are more stable. Furthermore, during the late Jurassic and throughout the Cre-

taceous the Cucullaeidae showed an amazing plasticity in the structure of the hinge teeth as exemplified by such a bizarre form as *Dicranodonta* (pl. 20, fig. 7), where the outline is much like the Glycymeridae, but the side teeth have become greatly elongated. The peculiar dentition of *Pseudocucullaea* (pl. 21, figs. 2, 3) also shows affinities with the Cucullaeidae, but it has almost attained the appearance of a heterodont pelecypod.

On the other hand, dentition similar to that found in the Glycymeridae has apparently evolved in several lineages from a cucullaeid-like dentition. *Trigonarca* (pl. 21, fig. 13), for example, has a hinge as well as some other morphologic features, like the Glycymeridae, but this genus does not appear to be ancestral to, or to have arisen from, the Glycymeridae. The same may be true of *Arcullaea* (pl. 21, fig. 4), *Peruarca* (pl. 20, fig. 5), and *Protarca* (pl. 21, fig. 10).

Although some of the Jurassic species of *Grammatodon* have an outline and ribbing resembling the Glycymeridae, particularly *Indogrammatodon* (pl. 21, fig. 8), the strongly asymmetrical hinge of the genus makes it a much less likely possibility as the ancestor of the Glycymeridae. The symmetrical hinge plate and teeth of the Glycymeridae (pl. 21, fig. 12) are most probably a modification of another symmetrical, or nearly symmetrical, hinge plate and teeth like that of the Cucullaeidae (pl. 21, fig. 9). It is interesting to note, however, that with the exception of the hinge teeth, *Grammatodon* and *Idonearca* have a remarkably similar shell morphology.

The Limopsidae have a hinge tooth pattern and shell outline like many Cenozoic species of the Glycymeridae, but other morphologic characters, particularly the ligament (pl. 22, fig. 12), are not like those in the latter family, and it is quite apparent that the similarities of morphology of the

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EXPLANATION OF PLATE 22

FIG. *1*—*Glycymeris* (*Glycymerita*) *sublaevis* (Sowerby). Lower Cretaceous, England. Right valve, ornamentation, ×5. (Copied from Woods, 1899, pl. 14, fig. 3d. Topotype in Wiltshire Collection, Woodwardian Museum.) (p. 92)

2—*Grandaxinaea laticostata* (Quoy and Gaimard). Pliocene, Castlecliff, Wanganui, New Zealand. Interior view, mature specimen, right valve, ×1. Hypotype in Stanford University Paleontology Type Collection. (p. 95)

3—*Glycymeris reevei* (Mayer). Recent, Philippines. Right valve, ornamentation, 5×. Hypotype in Stanford University Paleontology Type Collection. (p. 92)

4, 5, 8—*Glycymeris* (*Glycymerita*) *marullensis* (Leymerie). Lower Cretaceous, France. *4*, Exterior view; *5*, enlargement of cross section of ornamentation; *8*, enlargement of ornamentation. (Copied from d'Orbigny 1843–47, pl. 306, figs. 1, 4, 5.) (p. 92)

6, 7, 11—*Cucullaea vagans* Keeping. Lower Cretaceous, England. *6, 11*, Exterior views, ×1; *7*, ornamentation, ×3. (Copied from Woods, 1899, pl. 10, figs. 8, 9, 10. Types in Woodwardian Museum.) (p. 95)

9—*Glycymeris subcrenata* Wade. Upper Cretaceous, Coon Creek, Tennessee. Interior view, right valve, holotype, ×1. (Copied from Wade, 1926, pl. 11, fig. 8. Holotype U. S. National Museum no. 32733.) (p. 95)

10—*Postligata wordeni* (Gardner). Genotype of *Postligata*. Upper Cretaceous, Maryland. Interior view, right valve, syntype, ×5. (Copied from Gardner, 1916, pl. 21, fig. 7. Syntype in Maryland Geological Survey Collection.) (p. 95)

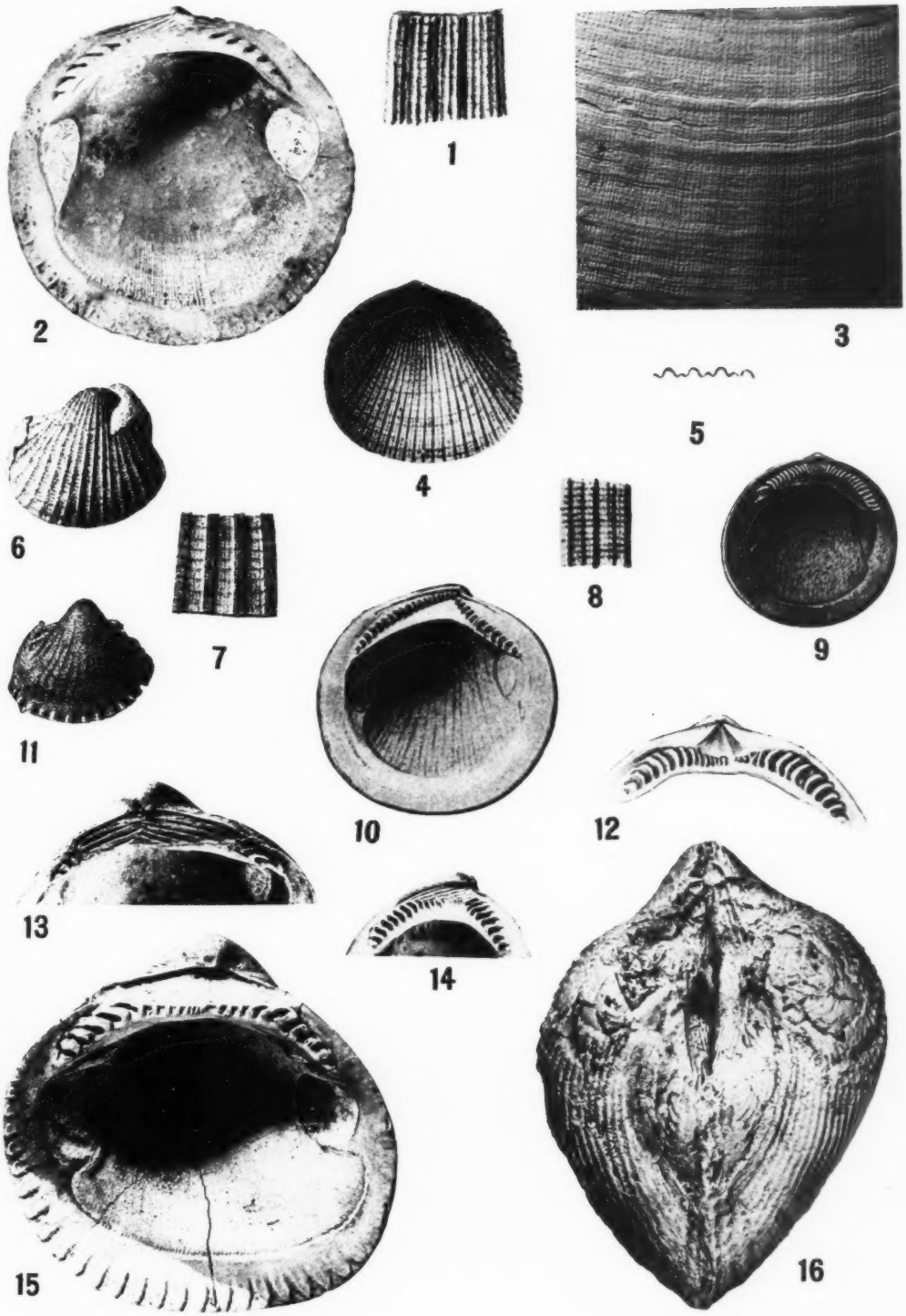
12—*Oblimopa macgillivrayi actaviva* Iredale. Genotype of *Oblimopa*—Family Limopsidae. Recent, Queensland. Figure showing hinge teeth, ligament, and beak. (Copied from Iredale, 1939, pl. 1, fig. 11a). (p. 96)

13—*Glycymeris* (*Pseudaxinea*) *insubrica* (Brocchi). Pliocene, France. Interior view, left valve, showing hinge teeth, ligament, and beak, ×1. Hypotype in Stanford University Paleontology Type Collection. (p. 95)

14—*Glycymeris* (*Axinactis*) *inaequalis* (Sowerby). Genotype of *Axinactis*. Quaternary, Manta, Ecuador. Interior view, right valve, showing hinge teeth, ligament, and beak, ×1. Hypotype in Stanford University Paleontology Type Collection. (p. 95)

15—*Glycymeris* (*Manaia*) *kaawaensis* Marwick. Lower Pliocene, Kaawa Creek, New Zealand. Interior view, right valve, ×1. Hypotype (topotype) in Stanford University Paleontology Type Collection. (p. 95)

16—*Glycymeris* (*Glycymerita*) *veatchii* (Gabb). Upper Cretaceous, California. View from posterodorsal border showing constricted area, ×1. Hypotype 5408 (Arnold's no. 1004) Stanford University Paleontology Type Collection. (p. 95)



Nicol, pelecypod family Glycymeridae

two families are due to convergent evolution. Iredale (1939, p. 241) has previously arrived at the same conclusion.

An excellent example of parallel evolution occurs in some late Cretaceous and early Eocene species of *Glycymerita* and *Idonearca* and is shown here (pl. 20, figs. 1–4).

The glycymerid type of tooth shape and arrangement, or slight modifications of it, is common in Recent prionodont genera and families. The cucullaeid type of tooth shape and arrangement is now scarce. The extremely developed side teeth, as shown in *Dicranodonta*, did not exist later than Cretaceous time.

Text figure 2 shows the probable path of evolution of the Glycymeridae from the Cucullaeidae. Any classification which widely separates these two families would certainly not be phylogenetically correct.

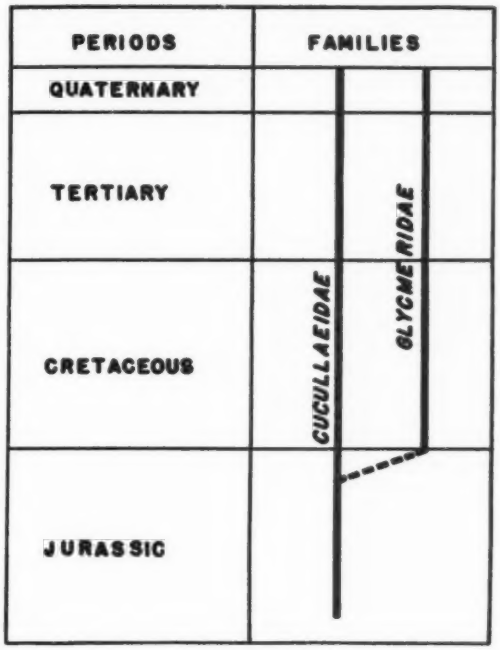


FIG. 2—Probable origin of the pelecypod family Glycymeridae from the Cucullaeidae.

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AN UPPER JURASSIC SEPIOID FROM CUBA

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ABSTRACT—In evidence that true sepioids existed in the Upper Jurassic, a new genus is described from the Jagua formation of western Cuba.

MANY modern students of cephalopods essentially follow d'Orbigny (1840, p. XXXVII) and use characters not ascertainable in fossils to group the Recent dibranchiate decapods into Oegopsida and Myopsida. Such a grouping seems to cut across any system based on the shell, which is after all a rather fundamental structure. From 1916 to 1922 Naef elaborated a classification applicable to both Recent and fossil forms (see Naef 1922, pp. 30–35, 296–300, or 1923, pp. 808–811), and which is therefore used here. Thiele (1934, pp. 952–983) uses an arrangement oriented for Recent forms, but not fundamentally incompatible with Naef's subdivision of the decapods into the three suborders Belemnoidea, Teuthoidea, and Sepioidea.

In Naef's view (1922, pp. 94–100) the sepioid stock was derived from some such belemnite as the Tithonian *Diplobelus*, the definitive separation supposedly having occurred at the very end of the Mesozoic, although in his diagram on p. 303 he projects the sepioid line back to the end of the Lias. On plausible morphological grounds within the Sepioidea he offers *Belemnosella* as an example of the basic type from which the rest of the suborder could have developed, and on the basis of the fossil record suggests that the wider differentiation into families began in the Paleocene.

In any case, no undoubted sepioids older than basal Eocene appear to have been found. Aside from such forms as *Campylosepia*, which may not even be cephalopods, the so-called sepioids heretofore reported from the Mesozoic have turned out to be teuthoids, as shown in particular by their lack of the characteristic phragmoconal deposit (for the Cretaceous *Actinosepia* the evidence is negative, Whiteaves (1898) making no mention of such a structure). Perhaps *Plagioteuthis* should be noticed, since it is reported from the Oxfordian near Moscow, Russia, and since Naef (1922, p. 93) remarks that it "has a certain resemblance" to *Belemnosis*, although he groups it among "spurious sepioids from older formations." Study of the original figures (Roemer 1890, p. 361) seems to justify the exclusion of *Plagioteuthis* from the Sepioidea.

The form described below from the Viñales region of Pinar del Río in western Cuba indicates that true sepioids existed as long ago as the older Upper Jurassic; following Imlay's summary (1942, pp. 1421–1423, 1435–1439), the age of this fossil is considered to be Argovian Oxfordian. Although in the absence of the apical end of the shell one can not be completely certain, the indications are that it may belong in the family Sepiidae, of which the oldest genera have been believed to be *Belosepia* (including *Stenosepia*) and *Pseudosepia* from the Eocene.

This Cuban form appears to be specifically and generically new; it is named in commemoration of P. L. Voltz of Strasbourg, who in 1830 indicated the relationship between the belemnites and the sepioids, and in recognition of the personal and scientific generosity of the late Robert H. Palmer of Habana.

Genus VOLTZIA Schevill, n. gen.
Genotype: *Voltzia palmeri* Schevill, n. sp.

Shell superficially resembling that of *Trachyteuthis*, but with the growth lines of the inner shell layers in the central field more prominent and chevron-shaped. Ventrally a convex axial deposit smaller than but resembling the phragmocone of *Sepia*. Rostrum and other apical structures unknown, lacking in available material. Soft parts unknown.

VOLTZIA PALMERI Schevill, n. sp.
Plate 23, figures 1–3

Shell elongate, with conspicuous growth lines showing in the inner shell layers of the central field. Dorsal surface tuberculate,

more finely toward edges. Lateral expansions (outer cone) narrow anteriorly, widest in posterior half (cf. *Trachyteuthis*); it should be noted that no sign of this structure appears on the right side of the holotype; only about the anterior two thirds of the paratype are preserved. Phragmoconal deposit on ventral side of rhachis, like that of *Sepia* but relatively smaller (perhaps because of the state of preservation); detailed structure not apparent in this material because of bituminous replacement, as is frequent in other fossils from this locality. Apical end lacking. Estimated total length of shell (holotype) about 7¾ inches; the paratype is about 5/4 as large. Holotype, M.C.Z. 5027; paratype M.C.Z. 5028.

Oxfordian Upper Jurassic (Argovian); Jagua formation.

Jagua Vieja, near Viñales, Pinar del Río, Cuba.

Comparison with other forms.—From all other sepioids the new form may be distinguished by the great width across the outer cone.

From *Belosepia* and *Sepia* it differs primarily in the smallness of the phragmoconal vestige, and in proportions. As may be seen in the transverse sections, taken about mid-length, in figures 3–5 of Plate 23, *Voltzia* is much more depressed than *Belosepia*, and even more than *Sepia*, although this may be partly a feature of preservation. The section of *Belosepia* given in our figure 4 is based on Edwards' restoration (1849, pl. 1, figs. 4, 5) of the unusual Dixon specimen from Sheppey, No. 39915 in the British Museum (N.H.). I am indebted to Dr. L. Bairstow of that Museum for informing me by letter that in this specimen "at least for the most part the phragmocone is represented only by a matrix-infilling of the alveolus, preserving the septal sutures but not the septa themselves. . . . We have no specimen in which the inner structure of the phragmocone is displayed as in Edwards, 1849, pl. I, fig. 6."

From more nearly contemporary teuthoids which it superficially resembles, *Voltzia* differs essentially in having the modified phragmocone characteristic of the sepioids. Examination of a series of Solnhofen-Eichstätt teuthoids in the Museum of Comparative Zoology bore out the statements of Quenstedt (1849, p. 494) and A. Wagner (1860, p. 756), failing to reveal any such structure on the smooth ventral side of *Trachyteuthis* or *Leptoteuthis*, any more than in *Plesioteuthis* or *Münsterella* (see p. 118) or, of course, in *Acanthoteuthis*. The absence of this phragmoconal structure in these specimens is not explainable by faulty preservation, since many of them retain indications of soft parts, such as arms and viscera. Although, as indicated above, there is no close relationship between *Voltzia* and *Trachyteuthis*, a comparison of their proportions may be helpful. In *T. hastiformis* (Rüppell) the greatest width across the pen and across the cone ("fins") is 25% and 35%, respectively, of the total length of the shell; in *T. latipinnis* (Owen) the figures are 30% and 45%. The corresponding measurements of *V. palmeri* are about 37% and 45%. It appears that the new form is appreciably less slender. In addition, the known material of *Voltzia* is much smaller than these teuthoids.

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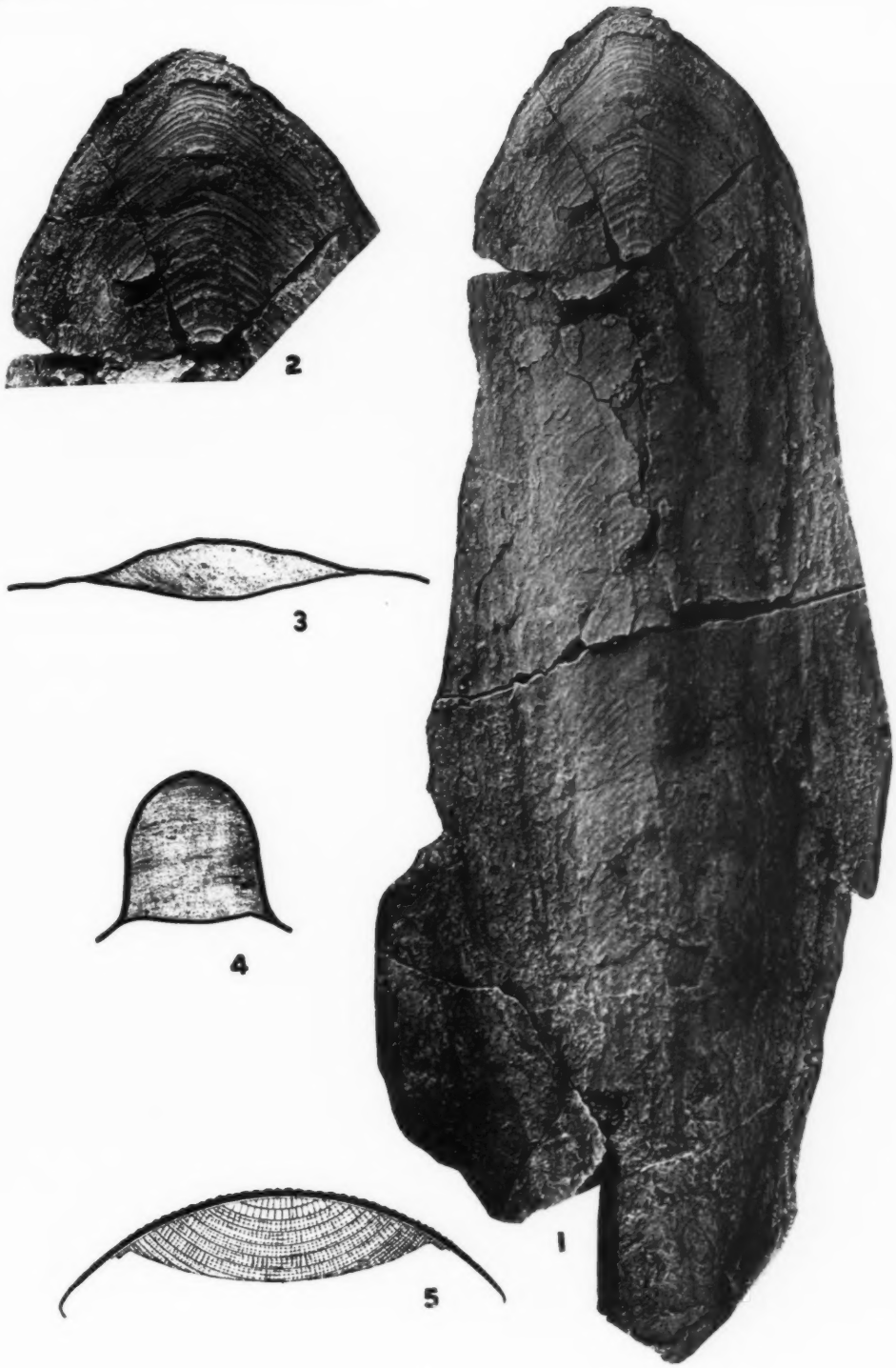
EXPLANATION OF PLATE 23

FIGS. *1–3*—*Voltzia palmeri* Schevill, n. gen., n. sp., holotype, M.C.Z. 5027. *1*, entire specimen, dorsal, ×1; *2*, detail of anterior end, ×1.25; *3*, mid-section, ×1. Figs. *1* and *2* from photographs by Dr. Alan B. Shaw.

4—*Belosepia*, mid-section, ×1. Based on Edwards 1849, pl. 1, figs. *4*, *5*.

5—*Sepia*, mid-section, ×1. From Naef 1922, fig. *36c*, p. 88.



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JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 1, PP. 102–106, 2 TEXT FIGS., JANUARY 1950

FOSSIL BURROWS FROM THE PRECAMBRIAN AJIBIK QUARTZITE OF MICHIGAN

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ABSTRACT—Sinuous markings have been found on the bedding surfaces of the Ajibik Quartzite near the Ropes gold mine north of the Marquette iron range in Michigan and are interpreted as burrows made by a small unknown organism. The formation is a hard white quartzite, steeply dipping to the south, and is generally accepted as Huronian in age. Helium age measurements indicate an absolute age greater than 1200 million years.

INTRODUCTION

THE "hard rock" below the Precambrian unconformity has been searched for evidence of life the world over—with fairly discouraging results (Raymond, 1939). The "fossils" that have been found range from fairly certain to very dubious and perhaps we may briefly review some of the discoveries.

Algae, "jellyfish," and "sponges" have been described from numerous localities in Canada (Walcott, 1912; Rutherford, 1929; Wilson, 1931), Finland (Sederholm, 1924 and 1925; Rankama, 1948), India (Srinivasa Rao, 1943, 1944, and 1946) and the United States (Walcott, 1899, 1915, and 1916; Grout & Broderick, 1919; Gruner, 1925 and 1946; White, 1928; Fenton & Fenton, 1936 and 1937; Bassler, 1941). Many of the discoveries are almost certainly true fossils, although the organic origin of some is open to question (Wilson, 1931; Hawley, 1926), and a few are thought to be definitely inorganic (Abbott, 1914; Raymond, 1939, p. 30) because of their similarity to known inorganic structures found in younger rocks. Algonkian "bacteria" are generally discredited on the grounds that their preservation seems improbable (Walcott, 1915; Raymond, 1939, p. 30).

Sederholm's *Corycium*, a primitive plant from the Archean of Finland, has been examined by Rankama (1948) who was able to demonstrate its organic origin on the basis of carbon isotope ratio determinations, performed on the *Corycium* graphite by A. O. C. Nier. Unfortunately, few other Precambrian fossils show graphitic preservation, but study of the C^{12}/C^{13} ratio in Precambrian graphites may prove interesting.

The radiolarites (lydites) in the "Spilitic étage" ($b\beta$, Algonkian) of the Barrandian System in western Czechoslovakia are generally believed to be organic in origin (Kettner & Bouček, 1936) although no distinct organic remains have been found in them (Bouček, personal communication). There is no question about the Algonkian age of the radiolarites.

"Algonkian linguloid brachiopods" have been described from the Vindhyan series of India by Chapman (1935) and from the Belt Series by the Fentons (1936). However, Chapman's many species of *Fermoria* have been reduced to one by Sahni (1935) who also expressed doubts that the fossils are indeed brachiopods. The specimens have been examined by Howell, who believes them to be plant remains, probably algae (private communication, 1948).

Many Indian geologists, however, now believe that the Vindhyan rocks are indeed not Proterozoic at all, but probably Cambrian in age (Rode, 1946; Misra, 1947; Auden, 1942). J. B. Auden of the Geological Survey of India writes: "Our trouble is that mostly we don't know in the first place where to draw the boundary between the Cambrian and the pre-Cambrian. On general grounds . . . I favour regarding most of the Vindhyans as Early Paleozoic" (private communication).

Two discoveries of Algonkian "crustaceans" have been announced in the literature, but neither has been accepted. The pictured organisms lack any definite form or texture, and one (Walcott's, 1899, *Beltina*) is probably of algal origin (Fenton & Fenton, 1936, p. 616), while the other (David and Tillyard's eurypterid, 1936) seems to be as-

sembled of carefully selected ferruginous concretions. Raymond (1935) briefly mentions the discovery of a true Precambrian arthropod by Stuart Weller in the Altyn limestone (Montana), but the fossil has never been described to the best of my knowledge.

Walcott and the Fentons have also described various trails and burrows from Precambrian rocks in the Belt series. Unfortunately, Walcott's descriptions (1899) are sketchy. The Fentons (1937, p. 1950, pl. 19, fig. 2) show filled, irregularly sinuous non-annulate burrows, 5.5 to 9 mm. wide, in coarse quartzite. "The annelids which made them followed a bedding plane between grey mud and nearly white sand, the burrow contours being discernible in both, though fillings are of sand." The trails described later in this paper show some similarity to the Fentons' specimens.

Thus goes the account of the described fauna of the Precambrian era. Only the meagerness of the array of known forms justifies any consideration of the otherwise unimportant specimens described below.

BURROWS FROM THE HURONIAN QUARTZITE

During the late summer of 1941, I accidentally collected a small slab of ripple-marked quartzite in the vicinity of the Ropes Gold Mine, north of Ishpeming, Michigan. Little importance was attached to the specimen until closer examination revealed gently curving and intersecting sinuous marks on the stratigraphically lower surface of the slab. (Fig. 1.) The marks were tentatively interpreted as fossil trails of some primitive organism, particularly interesting because of the well-established Middle Huronian age (Leith, Lund and Leith, 1935) of the Ajibik quartzite. Pressure of other duties unfortunately made it impossible to revisit the locality and the matter rested for seven years.

The opportunity to collect additional material arose in the summer of 1948 when Dr. W. Dennen of the Geology Department of M.I.T. kindly agreed to visit the locality near the Ropes Mine. He collected two small specimens and observed several others. Two trails measured approximately two feet long and five others ranged from 2 to 8 inches in length. The traces were 3 to 5 mm. wide, slightly raised, non-annulate, very gently to broadly sinuous, and in no case were they observed to branch distinctly. Thin sections (Fig. 2) cut through the specimens collected by Dr. Dennen show that the marks are not simple trails such as are produced by recent millipedes (Brady, 1947, pl. 68, fig. 2), gastropods (Fenton & Fenton, 1931; Raymond, 1922) or by floating objects dragging on the bottom. Instead, they appear to be uniform, sinuous ropes of sand, closely following the uneven bedding surfaces, but separated from them by a thin film of ferruginous material much the same as the coating of the bedding planes themselves (Fig. 2).

I am ignorant of the type of organism which made the burrows. It would appear that the animal was digging on the surface or at a slight depth, following the old bedding planes. Such behavior is not illogical, for a scavenger might very well find sufficient food on the old surface even if buried under a thin layer of new sand. The sand filling of the burrows may or may not have passed through the digestive tract of the creature, although the complete absence of annulate structure and the broad curves of the traces would seem to indicate that the movement was fairly rapid.

AJIBIK QUARTZITE

The quartzite is moderately pure, roughly 100 feet thick, massive on top, and thin-bedded near the base, dipping approximately 50° in a southeasterly direction. It is extremely hard and forms a conspicuous steep hogback in an area of otherwise moderate relief. The hardness of the rock makes it particularly difficult to secure specimens. Ripple-marks and crossbedding are common. The rock is fairly pure, and light colored, ranging from grey through white to pink. The color near the base is a darker grey, on a freshly broken surface. It is fine-grained, but some conglomerate stringers appear near the base, where it unconformably overlies the serpentine intruding Archean rocks of the Deer Lake Series. Near the top, the quartzite becomes darker and less pure, until it grades into the siliceous Siamo slate. There is comparatively little jointing but several transverse faults have displaced blocks by horizontal distances of the order of hundreds of feet.

1

2

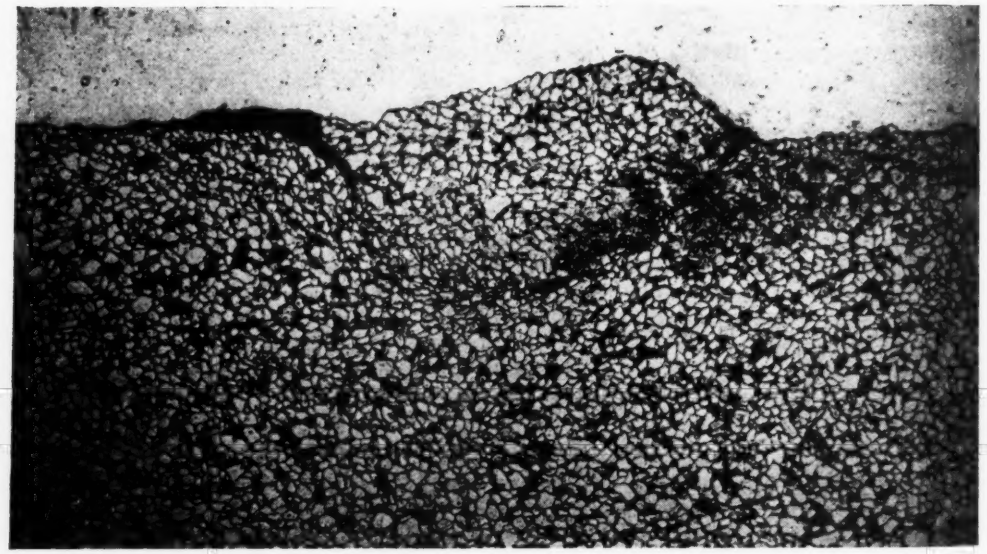

FIG. *1*—Lower surface of slab showing casts of several burrows, two of which cross. Reduced $\times\frac{3}{4}$. (Mus. Comp. Zool. No. 1017).
FIG. *2*—Transverse section of a burrow. Enlarged $\times 12.5$. (Mus. Comp. Zool. No. 1019).

Stratigraphic Relation and Absolute Age.—The Ajibik quartzite was laid down on a peneplaned terrane of greenstone and serpentine. The quartzite is about 100 feet thick and grades upward into the Siamo slate which, in turn, is conformably overlain by the Negaunee iron formation, a rock prolific in economic hematite deposits. Magnetite occurs in some of the mines and helium age determinations have been made on this material (Hurley and Goodman, 1943). Recently revised unpublished measurements by Hurley give an average age of about 1200 million years for magnetite from Republic, Michigamme, Champion, and Humboldt, Michigan. It is interesting to note that all four localities lie between 8 and 20 miles distant from the area where the burrows were found.

The magnetite crystals, 1200 million years old, may be considerably younger than the parent iron formation, which in turn is younger than the underlying Ajibik. It is clear from these considerations, that our fossils are of respectable antiquity.

LOCALITY

All specimens were collected in the SE ¼ of the SE ¼ of Sec. 30, T 48 N, R 27 W, Michigan, on the northwest slope of a steep hogback formed by the southerly flank of a projected mile-wide anticline of the Ajibik quartzite. The exact spot lies ⅛ mile northwest from a small lodge at the end of a wagon road. The lodge is near the SE corner of Sec. 30, approximately ½ mile from the highway, approximately 5/8 miles SSE from the Ropes Mine. The paved highway runs from Ishpeming past Deer Lake and on northward.

ACKNOWLEDGEMENTS

I am indebted to many colleagues for their help, suggestions and comments. Particular thanks are due Professor W. A. Kelly of Michigan State College, Dr. William H. Dennen of the Massachusetts Institute of Technology, Drs. V. P. Sondhi, J. B. Auden and P. N. Mukerjee of the Geological Survey of India; Professors P. E. Raymond and P. E. Cloud of Harvard University, Professor Franco Rasetti of Johns Hopkins University; Professor B. J. Howell of Princeton University; Dr. Fenton; and Professor Bedřich Bouček of Charles University, Praha.

Professor P. M. Hurley has kindly permitted the use of unpublished results of his helium age measurements.

The specimens are deposited in the Museum of Comparative Zoology, Harvard University; classified under *Vermes and Misc.*, Nos. 1017–1020.

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PALEONTOLOGICAL NOTES

A CHECKLIST OF CUBAN OSTRACODA

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During work in Cuba in the winter of 1946–1947 B. van Raadshooven, paleontologist with Shell Caribbean Petroleum Company, received a number of samples from P. Bermudez, now with Creole Petroleum Co. Mr. Van Raadshooven kindly allowed the writer to examine the washed material and to pick out the Ostracoda. As some of the samples show a good fauna this appeared to be an opportunity to prepare a checklist of 9 of these as an addition to the writer's thesis (v.d. Bold, 1946). At the same time some corrections to that study, not listed in M.B. Stephenson's review (Stephenson, 1947b) could be inserted. In this review Stephenson (p. 594) pointed out that the name *Cytheridea* (*Haplocytheridea*) *reversa* v.d. Bold (v.d. Bold, 1946, p. 80, pl. 7, fig. 11, pl. 8, fig. 6) is preoccupied by *Cytheridea reversa* Egger (1858, p. 414). The name *Haplocytheridea chicoyensis* n. nom. is proposed for this species from the Miocene of Cuba and Guatemala. The L. Eocene species from Guatemala called *Cythereis costellata* (Roemer) (v.d. Bold, 1946, p. 95, pl. 12, fig. 1) is apparently the same as. *Leguminocythereis? applinorum* Swain (1946, p. 370, pl. 54, fig. 11, pl. 55, fig. 10). The second name should be adopted as identification with the German species is by no means certain.

Comparison with Jackson and Vicksburg material (kindly donated by H. V. Howe of Louisiana State University and recently received through the courtesy of L. Weingeist, paleontologist with Creole Petroleum Co.) shows that *Bythocypris cf. gibsonensis* Howe and Chambers (1935) from the Oligocene of Cuba (v.d. Bold, 1946, p. 68, pl. 1 fig. 13) is in fact this species. *Cythereis cubensis* v.d. Bold (1946, p. 91, pl. 10, fig. 22) is identical with *Cythereis blanpiedi* Howe. The writer was misled by the slightly exaggerated median ridge in Howe's figure (Howe and Law, 1936, pl. 4, fig. 27). *Cythereis rosefieldensis* Howe and Law (1936, p. 51, pl. 3, fig. 26, pl. 4, fig. 1, 2) is considered to be the adult form of *Cythereis spinosa* Lienenklaus (v.d. Bold, 1946, p. 90 pl. 10 fig. 10), which species is probably not identical with *Cythereis spinosa* Lienenklaus (1900, p. 516, pl. 20, fig. 4). *Cythereis davidwhitei* Stadnichenko (1927, p. 240, pl. 39, fig. 24) was not recognized by the present author and erroneously described as *Cythereis splendens* Sutton and Williams (?) (v.d. Bold, 1946, p. 94). *Cythereis evax* (Ulrich and Bassler) (v.d. Bold, 1946, p. 90, pl. 10, fig. 19) has been found in the Cooper marl (? U. Eocene) of North Carolina (H. V. Howe material). So far it has not been found in deposits younger than middle Oligocene of the Caribbean region, which throws some doubt on the correctness of the writer's determination. *Cythereis evax* (Ulrich and Bassler) was originally described from the Miocene of Maryland (Ulrich and Bassler, 1904, p. 115, pl. 36, fig. 6–8). Howe does not report it from the Arca zone of the Choctawhatchee; the present author was unable to find it in samples from the Shoal River, Oakgrove and Chipola Miocene of Florida (H. V. Howe's material) and in a type collection of Ostracoda from the Miocene of Florida, made by Hendee Smith and in the possession of R. W. Barker (senior paleontologist with the S. C. P. C.). *Triebelina sp.* (v. d. Bold, 1946, p. 74, pl. 5, fig. 5) is identical with *Triebelina howei* (Stephenson) (*Glyptobairdia howei* Stephenson, 1946, p. 347, pl. 42, fig. 5, 6, text fig. 1, 2; *Triebelina howei* (Stephenson), 1947a, p. 578).

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TABLE 1. OCCURRENCE OF SOME FOSSIL CUBAN OSTRACODA

	10 U. Cretaceous	538 U. Cretaceous	20 L. Eocene	337A M. Eocene	18 U. Eocene	36 U. Eocene	209 L. Oligocene	7 M. Oligocene	39 M. Miocene
Cytheralla cubensis v.d. Bold							×	×	
Cytherella dozyi v.d. Bold		×							
Cytherella sp. Howe & Chambers						×			
Cytherella sp.			×						
Argilloecia hiwanneensis Howe & Lea					×		×	×	
Argilloecia sp.				×	×		×		
Paracypris franquesi Howe & Chambers				×		×			
Paracypris sp.			×						
Macrocypris cylindracea (Bornemann)					×				
Bythocypris gibsonensis Howe & Chambers				×		×	×		
Bairdia trigona (Bosquet)	×	×							
Bairdia cespedesensis v.d. Bold			×						
Bairdia cassida v.d. Bold			×			×			
Bairdia hiwanneensis Howe & Lea							×		
Bairdia antillea v.d. Bold									×
Bairdia sp.		×	×	×			×		×
Triebelina howei (Stephenson)								×	
Krithe cubensis v.d. Bold			×		×	×	×	×	
Krithe bartonensis (Jones)				×	×	×			
Krithe hiwanneensis Howe & Lea							×		
Cytheridea limburgensis v. Veen		×							
Clithrocytheridea grigsbyi (Howe & Chambers)				×	×	×			
Cythereis evax (Ulrich & Bassler)						×	×	×	
Cythereis ozanana Israelsky		×							
Cythereis blanpiedi Howe			×	×	×				
Cythereis blanpiedi, var. *mammidentata* v.d. Bold							×		
Cythereis polytrema (Brady)							×		
Cythereis rosefieldensis Howe & Law							×		
Cythereis davidwhitei Stadnichenko			×						
Cythereis montgomeryensis Howe & Chambers					×				
Hemicythere antillea v.d. Bold									×
Hemicythere kniffeni Howe & Law							×	×	
Hemicythere stolonifera (Brady)					×		×		
Brachycythere ledaformis (Israelsky)	×	×							
Prachycythere russelli Howe & Law							×	×	
Cytheromorpha sp.								×	
Loxoconcha cf. corrugata Alexander							×		
Loxoconcha dentata (Lienenklaus)			×		×				
Loxoconcha sp.			×						×
Cytheropteron montgomeryensis Howe & Chambers					×				
Cytheropteron punctulata Lienenklaus							×		
Cytheropteron sp. Howe & Law							×		
Cytheropteron danvillensis Howe & Chambers						×			
Cytherura sp.						×			
Paracytheridea sp.				×					
Monoceratina sp.						×			
Pseudocythere cretacea Bonnema						×			
Xestoleberis sp.		×							

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AMMONITES: TETRABRANCHIATA OR DIBRANCHIATA?

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In a recent preliminary note A. Jeannet (1948) reports and illustrates some observations on the shape of the apertures of some nautiloids from the late Jurassic ferruginous oölites of Herznach (Argovie), Switzerland.

These observations are undoubtedly valuable, but exception must be taken to some of the author's inferences:

(1) For the new classification of the Nautiloidea "toute différente de celle, utilisée de nos jours et proposée par L. F. Spath en 1927," as announced by him (p. 178), his future paper will have to be awaited. In passing it may, however, be noted that the new subfamily (of the family Nautil dae?) already proposed in Jeannet's preliminary paper should, according to the rules of nomenclature, be named Mesonautilinae but not Mesonautilidae.

(2) Jeannet (p. 185), after stating "striking analogies" between "les impressions situées a l'intérieur et dans le fond de la loge habitée d'un Nautile actuel (*N. pompilius* L.)" and the apertures of certain fossil nautiloids, concludes:

"On pourrait exprimer les faits de la façon suivante: La chose se passe comme si la forme du péristome de certaines espèces fossiles avait émigré vers le fond de la loge habitée d'un Nautile actuel et s'était fixée dans le contour de certaines des impressions du manteau."

These impressions in the rear of the body chamber of *Nautilus pompilius,* here brought into such a fascinating evolutionary connection with the apertures of some Mesozoic nautiloids, are, however, most probably nothing else than those of the muscles of attachment, as clearly seen, ahead of the last septum, in Foord's (1891, p. 170) figure 32a; those muscles, themselves, are explicitly described in Zittel-Eastman (1913, p. 588) and are found, under the designation "h," in Owen's illustration of the interior of the living *Nautilus,* reproduced in that textbook (*ibid.*, p. 587) as figure 1049.

(3) Furthermore, Jeannet (p. 186) states rather categorically that, whereas in the nautiloids the ventral part of the apertural margin is either straight or inflected backward, in the ammonoids the "appendice siphonal," if existing, is always directed forward but not backward, and that there is never a ventral sinus. This statement is, however, inconsistent with the enumeration, in Zittel-Eastman (1913, p. 623), of several late Paleozoic ammonoid families in which a hyponomic sinus is present, either throughout the family and throughout development, or in some species only, or in all stages except the gerontic one.

However, even if Jeannet's above statement were correct, it still could not justify his—admittedly hypothetical—conclusion that the nautiloids should be referred to the Tetrabranchiata but the ammonoids to the Dibranchiata. In no way does the author make it clear why a backward inflection of the ventral part of the apertural margin in some forms of a group should indicate the presence of four gills throughout this group, but its forward projection that of only two. Thus, his conclusion appears to be untenable from a purely logical angle and is even

less apt to refute the generally accepted[1] reference of the Ammonoidea to the Dibranchiata, obviously based on the fact that their affinity to the living *Nautilus* species is, in every respect, much closer than that to the orders of the Belemnoidea, Sepioidea, and Octopoda which, in their entirety, constitute the subclass Dibranchiata.

[1] Jeannet (p. 186) says that the ammonites are referred by the authors either to the Tetrabranchiata or to the Dibranchiata, but he fails to quote any author who favors the latter opinion.

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PALEOGEOGRAPHY AND NOMENCLATURE—ANOTHER COMMENTARY

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E. S. Richardson, Jr. (1948) recently published a short note in which he announced the discovery of the South American trilobite *Parabolina andina* (Hoek) in collections from Newfoundland. Richardson also discussed the possibility that many species with great geographic or stratigraphic ranges may exist but that they may be masquerading under several names because of the paleontologists' predilection for changing specific names across stratigraphic boundaries or between widely separated localities.

Richardson's article evoked a commentary from N. D. Newell (1949), who questioned the method of identification of *P. andina* on the grounds that no statistical methods seem to have been used in making the comparisons. Newell also raised objections to the great range in latitude shown by *P. andina*, pointing out that very few modern marine invertebrates have the ability to span the equatorial region.

It is the purpose of this note to cite another example of a wide-ranging trilobite, *Parabolinella triarthroides* Harrington, 1938, and to offer an alternative explanation for these cosmopolitan species.

P. triarthroides was originally described from the Tremadocian of Argentina; Specimens indistinguishable from it have been found in the uppermost Cambrian rocks of northwestern Vermont (the upper part of the Gorge formation). The fauna which includes these trilobites is the subject of a separate paper now in preparation, but Newell's note has prompted this preliminary account of its discovery.

The identification of the Vermont specimens as *P. triarthroides* is supported by a statistical analysis, the lack of which Newell felt to be detrimental in the case of *P. andina*. A comparison of the Vermont specimens with the described species of *Parabolinella* and *Parabolina* (more than 30 in all) led the author to the conclusion that the former were the same as the South American species. In order to check this qualitative opinion, a statistical analysis was made of 44 Vermont cranidia; after this had been completed, the measurements presented by Harrington in the original description of *P. triarthroides* were compared with those of the Vermont specimens, and the two were found not to differ significantly.

It is possible that the trilobites from Vermont and Argentina are identical homoeomorphs, but if they are not separable on

either qualitative or quantitative grounds, are we justified in using two specific names for them? Two names would represent only a subjective separation and would have no objective basis or application. In extinct groups, identical homoeomorphs that are not widely separated stratigraphically must be regarded as the same species, for if species are to be separated solely upon the grounds that *they ought to be different*, taxonomy at the species level will fall into a chaotic state.

It seems to the present author to be a weakness in Newell's argument that his analogies are based largely upon modern marine invertebrates, which are restricted in their meridional range by the sharply defined climatic zones that now girdle the earth. By using these analogies Newell implies that the climates of the past have always been sufficiently differentiated into zones to have restricted species as narrowly in their range as today.

Objections can be raised to this implication. Whereas the existence of climatic zones is a function of latitude, the sharpness of delineation of climatic zones is in part a function of the relative development of land and sea, the zones being better defined during times of exposure than in times of inundation. All available evidence indicates that the late Cambrian and early Ordovician were times of great flooding in both of the Americas, and at such a time the climatic zones would have been particularly ill-defined. In contrast, we are now living in a time of unusually widespread emergence, with the concomitant sharpening in definition of climatic zones. Moreover, this is a cryogenic period, there is ice at both poles; this unusual circumstance increases still further the delineation of climatic belts and renders still more dangerous the practice of comparing ancient and modern climates and climatic zones.

It seems to follow, therefore, that the climatically limited ranges of modern species are not directly comparable with the ranges of species living during most of geologic time. Moreover, such comparisons seem to be especially inapplicable to Ordovician species. It seems likely that as more quantitative studies are made upon the benthonic and pelagic species of the early Paleozoic, a greater, rather than a smaller, number of cosmopolitan species will come to be recognized.

Another explanation of the seemingly anomalous ranges of *P. andina* and *P. triarthroides* has not been mentioned by either Richardson or Newell. It seems possible to the writer that as a result of migration of the poles (or movements of the sialic layer, which would produce the same net effect), the present meridional separation of the North and South American localities is greater than that which existed in Cambro-Ordovician times.

Migration of the poles by movements of the sial has long been advocated by proponents of the theory of continental drift, but rejection of the Wegener hypothesis has led many to overlook the value of polar migration, independent of continental drifting, as an explanation of faunal distribution. Grabau (1936) suggested that in the late Cambrian and early Ordovician the North Pole lay in northern Africa. If this assumption is accepted, with the present distribution of land masses, the localities in Argentina and Newfoundland would have been, respectively, about ten and thirty degrees north of the equator, with the Vermont locality almost midway between. If continental drifting is invoked, and the primordial continent, Pangaea, is restored (which this writer does not advocate), the meridional separation of the Agentine, Newfoundland, and Vermont localities is still further reduced.

In summary, it seems probable that species may actually have had much greater geographic ranges under the equable climates of the early Paleozoic than is common at present, and that the present distribution of some species of fossils may be attributable to the effective migration of the poles.

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EMENDATION OF *ENDELOCRINUS TUMIDUS* (STRIMPLE)

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In 1940, Moore and Plummer proposed the genus *Endelocrinus* based primarily on the presence of dimple-like depressions found at the angle of meeting between plates of the dorsal cup. There are a large number of forms having this characteristic, which makes the genus useful. However, as a matter of record the author would like to mention that very few small calices of delocrinids are found which do not have these depressions. Considering the vast number of large calices belonging to *Delocrinus* (i.e., without said depressions) one is inclined to wonder why a comparable number of young specimens are not found. At numerous Pennsylvanian horizons, small specimens of *Erisocrinus* are found along with large specimens, and the same is true of *Apographiocrinus* and other reasonably common genera. It could be that many forms, now being considered as *Endelocrinus*, are in reality the young of *Delocrinus*. The arm structure of some forms assigned to *Endelocrinus* is slightly different from that normally associated with *Delocrinus* and it appears practical to recognize and use the genus *Endelocrinus* unless, or until, it is proven to be congeneric with *Delocrinus*.

Study of the Pennsylvanian endelocrinids is somewhat hampered by an oversight on the part of the author in presenting the species *Endelocrinus* (*Delocrinus*) *tumidus* (Strimple), (1939, pp. 8–9). It might be explained that intimate segregation of apparently closely comparable forms into distinct species, and even genera, was not contemplated by the writer at the time and for that reason, designation of the holotype was not made. Most of the description was based on that specimen figured on plate 2, figs. 6 and 7, which was intended, and is here designated as the holotype. The description of *E. tumidus* is therefore emended and restricted with regard to the first primibrach to include only forms having tumidity without spine-like projections in upper portion of PBr. The two specimens figured in plate 2, figs. 1–5, are closely related to but not identical with *E. tumidus*. The specimen with a portion of the arms attached, which is figured in plate 2, figures 4 and 5, is taken as the holotype of *Endelocrinus tumidus spinosus* new subspecies. The dorsal cup figured as plate 2, figures 1–3, is taken as a paratype. Aside from the difference in structure of PBrBr, the basal and radial plates are more tumid in *E. tumidus* than those of *E. tumidus spinosus*.

Calices have been observed in the same horizon (Wann formation, Ochelata group, Missourian), which could be referred to *E. grafordensis* Moore and Plummer (1940), but no crowns have as yet been found by the author which could be considered as belonging to that species. Crowns assignable to *E. grafordensis* have been personally observed in slightly higher horizons of the Missourian of northeastern Oklahoma. The dorsal cup of this species is somewhat larger and has a proportionately greater height than in *E. tumidus* or *E. tumidus spinosus*.

The weak limestone and associated shales exposed at the hill, locally termed "the Mound," just west of Bartlesville, Oklahoma, has been designated by this and other authors as Stanton limestone formation, Plattsburg-Lansing formation, Birch Creek limestone formation and Wann formation. The fauna is comparable to that of several exposures found to the south of Bartlesville which are considered to be Wann formation. It is different from faunas associated with the Birch Creek limestone. The author considers the sandstone occurring at the top of the hill in question to be the Torpedo sandstone and the crinoidal limestone and shales which occur just below mid-height of the hill to be the Wann formation. This observation may be readily substantiated by examination of the strata exposed in the escarpment one mile to the west where the Torpedo sandstone is easily identified.

The form described as *E. parvus* Moore and Plummer (1940, pp. 303–306) is placed into synonomy as equivalent to *E. tumidus* (Strimple). Necessity of this action was

recognized by Moore and Plummer (1940, p. 305).

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COPE'S TYPES OF FOSSIL REPTILES IN THE COLLECTION OF THE BUREAU OF ECONOMIC GEOLOGY, THE UNIVERSITY OF TEXAS

JOHN ANDREW WILSON
Department of Geology, The University of Texas

The synonymies and catalogue numbers of Cope's types of fossil fishes have been given in a previous note (Wilson, 1948). As many of the types of fossil reptiles as could be expected from Montgomery's (1904) list have been located at The University of Texas and catalogued. He listed seven specimens but remarked that the material of *Testudo turgida* and *T. pertenius* "is in a very fragmentary condition and not marked 'type' but probably is a portion of the type material." O. P. Hay added notes to some of the labels stating that they are probably the types of *T. turgida* or *T. pertenius*. It is still impossible to be certain of the identification of the types of these two species; therefore they are not included in this list.

In addition to the material located by Montgomery, the author discovered several bones and fragments bearing the label "*Episcoposarus haploceros* Cope, Remainder of bones from typical and original locality. 5/25/92." (*Haploceros*, by error on the label, should read *haplocerus*.) This material is apparently part of the original type which is in the collection of the Academy of Natural Sciences of Philadelphia (A.N.S.P. 14688). The Austin specimen, however, cannot safely be interpreted as more than a topotype. Cope did not publish figures of *E. haplocerus*, so figures 1–3 are included here

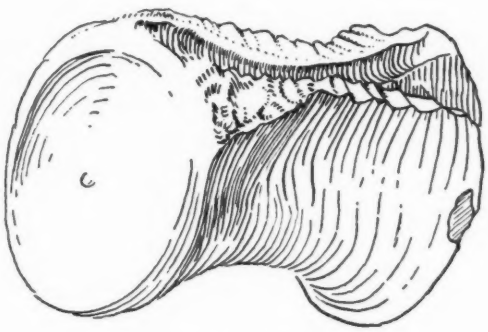

FIG. 1—*Episcoposaurus haplocerus* Cope. Oblique view of dorsal vertebra. ×⅔.

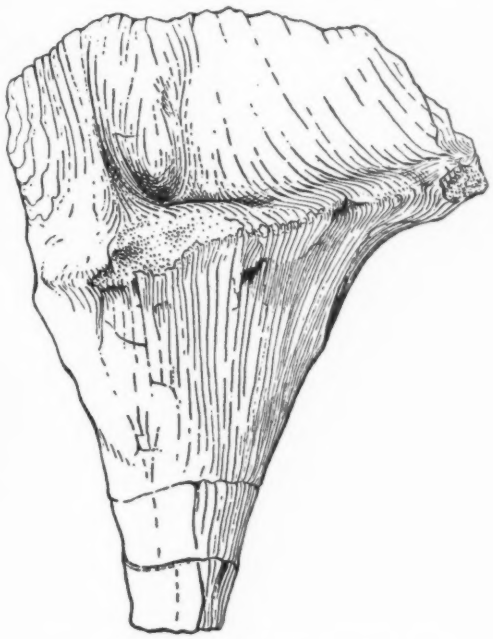

FIG. 2—*E. haplocerus* Cope. Ventral view of lateral dermal plate. ×⅔.

to illustrate the topotype material at Austin. The writer is indebted to The University of Texas Research Institute for a grant to defray cost of making these illustrations.

All of the specimens which are unequivocal types are, in the author's opinion, too fragmentary to be determined specifically; the phytosaur teeth, *Palaeoctonus dumblianus* and *P. orthodon*, can only be identified as to family.

PALAEOCTONUS DUMBLIANUS Cope 1893

Palaeoctonus dumblianus COPE, 1893, Geol. Survey Texas, 4th Ann. Rept. 1893, p. 16, pl. 2, figs. 4–6; HAY, 1902, U. S. Geol. Survey Bull. 179, p. 490; MONTGOMERY, 1904, Biol. Bull., vol. 8, p. 57; HUENE, 1926, U. S. Nat. Mus. Proc., vol. 69, art. 18, p. 4; HAY, 1929, Carnegie Inst. Washington Pub. 390, vol. 2, p. 172.

"*Palaeoctonus dumblianus*" Cope. CAMP, 1930, California Univ., Mem. vol. 10, p. 145. (Cited by Camp in this form.)

Palaeorhtinus dumblianus Cope. MEHL, 1915, Jour. Geology, vol. 23, p. 164 (by error).

Palaeoctonus (*Clepsysaurus*) *dumblianus* Cope. CAMP and VANDERHOOF, 1940, Geol. Soc. America Spec. Paper no. 27, p. 429. (Cited by Camp and Vanderhoof in this form.)

Bureau of Economic Geology Coll. No. 18563. The only specimen found is illustrated in Cope's figure 5.

PHYTOSAURUS SUPERSCILIOSUS (Cope) 1893

Belodon superciliosus COPE, 1893, Geol. Survey Texas, 4th Ann. Rept. 1893, p. 12, pl. 1, figs. 1–10; MONTGOMERY, 1904, Biol. Bull., vol. 8, p. 57; MEHL, 1915, Jour. Geology, vol. 23, p. 163.

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?"*Phytosaurus*" *superciliosus* (Cope). HUENE, 1926, U. S. Nat. Mus. Proc., vol. 69, art. 18, p. 5. (Cited by Huene in this form.)

Bureau of Economic Geology Coll. No. 18562.

TESTUDO HEXAGONATA Cope 1893

Testudo hexagonata COPE, 1893, Geol. Survey Texas, 4th Ann. Rept. 1893, p. 77, p. 22, fig. 2; DUMBLE, 1894, Jour. Geology, vol. 2, p. 564; HAY, 1902, U. S. Geol. Survey Bull. 179, p. 451; GIDLEY, 1903, Am. Mus. Nat. History Bull., vol. 19, p. 623; MONTGOMERY, 1904, Biol. Bull., vol. 8, p. 57; HAY, 1908, Carnegie Inst. Washington Pub. 75, pp. 398, 463, figs. 625, 626; HAY, 1924, Carnegie Inst. Washington Pub. 322A, p. 239; HAY, 1929, Carnegie Inst. Washington Pub. 390, vol. 2, p. 103.

Bureau of Economic Geology Coll. No. 18566.

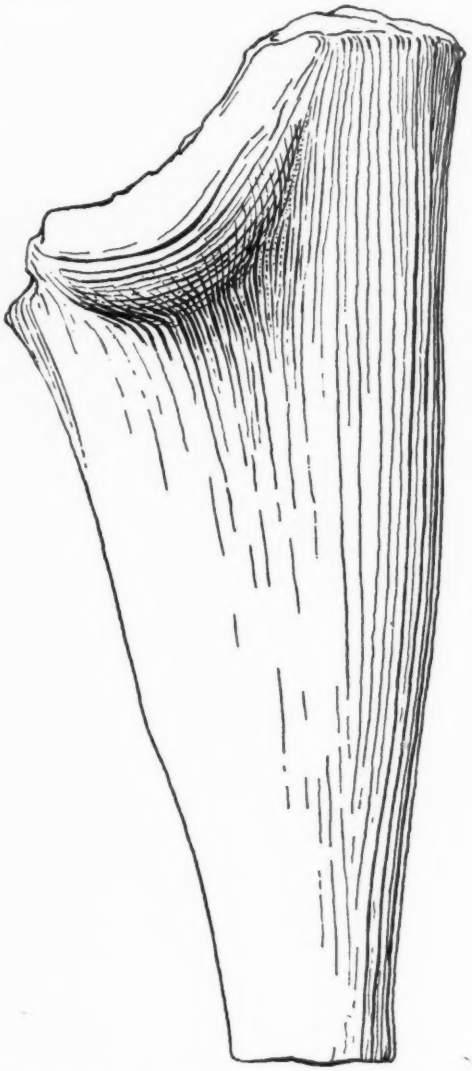

FIG. 3—*E. haplocerus* Cope. Anterior view of lateral dermal plate shown in figure 2. ×¾.

TESTUDO LAUTICAUDATA Cope 1893

Testudo lauticaudata COPE, 1893, Geol. Survey Texas, 4th Ann. Rept. 1893, p. 75, pl. 22, fig. 1; DUMBLE, 1894, Jour. Geology, vol. 2, p. 564; HAY, 1902, U. S. Geol. Survey Bull. 179, p. 451; GIDLEY, 1903, Am. Mus. Nat. History Bull., vol. 19, p. 623; MONTGOMERY, 1904, Biol. Bull., vol. 8, p. 57; HAY, 1908, Carnegie Inst. Washington Pub. 75, pp. 398, 462, figs. 623, 624; HAY, 1924, Carnegie Inst. Washington Pub. 322A, p. 239, HAY, 1929, Carnegie Inst. Washington Pub. 390, vol. 2, p. 104.

Bureau of Economic Geology Coll. No. 18565.

Additional specimens which were collected by Cope or others at the same time but which are not types or are questionable types are listed as follows:

?*Palaeoctonus orthodon* Cope.—A tooth which agrees in size to measurements given by Cope (1893) and described by him as follows: "The basal part of a large tooth, probably of this species, was obtained by Mr. Cummins at the same time and place."

Bureau of Economic Geology Coll. No. 18564.

Testudo pertenius Cope.—Hay (1908) says: "Of this species the writer found in The University of Texas only three or four large fragments which had been glued to sheets of paper. These fragments may or may not belong to the type." Bureau of Economic Geology Coll. No. 18567.

Testudo turgida Cope.—Hay (1908) says: "The writer examined the materials in the collection at The University of Texas, at Austin, but was not able to find Cope's type of the species. Remains of two or three other specimens of the species are in the collection, ..." These specimens with Hay's notes on the labels have been found and are catalogued under one number.

Bureau of Economic Geology Coll. No. 18568.

Episcoposaurus haplocerus Cope.—See above and figs. 1–3. Bureau of Economic Geology Coll. No. 18569.

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MULTISOLENIDA, A NEW ORDER OF THE SCHIZOCORALLA

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In 1937 (1) I described the new coral genus *Multisolenia* (genotype *M. tortuosa*) from the Lockport formation of Mann Island, Lake Temiskaming, in northern Ontario. At that time it was pointed out that the peculiar characteristics possessed by this

genus were so unique that it might well serve as the basis of a new order or even subclass.

The nature of the corrallum, corallites, and septa suggest the Order Chaetetina of the Schizocoralla (2). The presence of numerous, well-developed solenia, however, may possibly link the genus with the Alcyonaria.

While the solenia are outstanding features, nevertheless, the mode of fission is so like that shown by the Schizocoralla as a whole that inclusion in that subclass seems warranted. I therefore propose the name Multisolenida as a fourth order of the Schizocoralla, as well as the new Family Multisolenidae. At present this family will include only the genus *Multisolenia*.

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REVIEW

Die Lebensweise der Dinosaurier, by Martin Wilfarth. 95 pp., 60 figs., 3 pls. Paper. Price $3.60. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1949.

This work is, as the author admits, based on hypothesis. The author assumes that during Mesozoic times the tides were much greater than they are at the present day. Having assumed this, he goes on to the next and logical assumption, namely, that there were great areas along the shorelines that were periodically flooded and laid bare by the tremendous tides. He also assumes that the periods of tidal fluctuation during the Mesozoic were very long—on the order of days and months instead of six hours as at present.

Having made these assumptions he proceeds to build a picture of the dinosaurs as being adapted to life partially on the tidal flats and partially under water. He imagines the dinosaurs feeding along the shore, in shallow water, and also in waters of considerable depth. He postulates that when the dinosaurs got into deep water they were able to walk along the bottom to feed, and to float up to the surface periodically to breathe. The bulk of his paper is devoted to the elucidation of these assumptions as they would apply to the several suborders of dinosaurs.

The work is so completely without basis, either geological, paleontological or anatomical that it need not be taken seriously. Perhaps the only thing about this paper more fantastic than the thesis and its development is the price that is being asked for it.

Edwin H. Colbert

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NOMENCLATURAL NOTES

EXAMPLES OF SYNONYMOUS HOMONYMS

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O. Haas (1949, Jour. Paleontology, vol. 23, no. 5, pp. 573–574) recently has noted the theoretical "possibility of synonymous homonyms" at the generic level. Although the independent proposal of two identical names for a genus would be an unusual phenomenon, dual synonymy and homonymy at the specific level has happened all too often. The following examples were applied to Foraminifera that have been recorded from the Upper Cretaceous of Texas. More could be found, no doubt, by a search extended taxonomically, stratigraphically, and geographically.

Arenobulimina americana Cushman, 1936 (Cushman Lab. Foram. Research, Special Publ., vol. 6, p. 27), and *A. americana* Brotzen, 1936 (Sver. Geol. Unders., ser. C, no. 396, p. 42), were proposed almost simultaneously for the same common American species.

Nodosaria zippei Reuss var. *alternata* Jones, 1886 (Belfast Nat. Field Club, Proc., app. 9, p. 330), currently known as *Dentalina alternata* (Jones), has *N. alternata* Carsey, 1926 (University of Texas, Bull. 2612, p. 35), as junior homonym and synonym. One may infer that this anomaly arose from failure to document a correct identification with *N. alternata* Jones. The name *alternata*, then, presumably was confused with a series of oddly derived new names including *rosetta*, *bulletta*, *plaita*, and *lineara*.

A somewhat more involved case is that of *Anomalina wadei* W. Berry, 1929 (U. S. Nat. Mus., Proc., vol. 76, no. 19, p. 14), and *Truncatulina wadei* W. Berry, 1929 (*op. cit.*, p. 12), in which the homonymy is secondary. Fortunately, both names (together with *Cibicides subcarinatus* Cushman and Deaderick, 1944, Jour. Paleontology, vol. 18, no. 4, p. 341) are synonyms of *Cibicides coonensis* (W. Berry), 1929 (*op. cit.*, p. 14, as *Anomalina;* not *Truncatulina coonensis* W. Berry, 1929, op. cit., p. 12, = *Cibicides berryi* Cushman).

The obvious moral pointed by these nomenclatural oddities is that some caution, as well as ingenuity, might advantageously be applied to the naming of new species, and that trivial names should not be duplicated in closely allied genera.

MÜNSTERELLA, NEW NAME FOR *KELAENO* MÜNSTER 1842, NON MÜNSTER 1839

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The compilation of an index of cephalopod genera and their type species has called attention to nomenclatural confusion in the case of *Kelaeno* Münster 1842, a Jurassic teuthoid genus from Solnhofen.

Both *Kelaeno* Münster 1842 (p. 95) and the emendation *Celaeno* A. Wagner 1859 (col. 274, 278) are preoccupied by *Kelaeno* Münster 1839 (p. 94) and *Celaeno* R. Owen 1844 (pp. 81, 84), both of which are synonyms of *Acanthoteuthis* R. Wagner in Münster 1839 (p. 94), and by *Celaeno* Leach 1821 (pp. 69, 70). For *Kelaeno* Münster 1842 the name *Münsterella* nov. nom. is proposed, the genotype being *Kelaeno scutellaris* Münster 1842, first fixed by A. Wagner 1859 (col. 278; also 1860, p. 780) in synonymizing *K. arquata* Münster 1842, there having been only two originally included species.

Listroteuthis Naef 1922 (p. 153) might be considered available for this purpose, but

Naef's representations of significant structural differences in his genotype, *Celaeno conica* A. Wagner 1859, appear to justify its generic separation from *Kelaeno scutellaris* Münster 1842.

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JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 1, PP. 119–120, JANUARY 1950

NOTICES

The committee on the Illustrated Catalogue of North American Devonian Fossils announce the publication of the second instalment of cards on the corals. This unit (1-E, part b) covers the first half of the family Favositidae, and contains 145 cards. The cards for the remaining Favositidae also have been completed by E. C. Stumm, and they will form the next publication unit, appearing in 1950.

Unit 1-E, part b is priced at $13.00, with packing and postage extra. Copies of this and other units previously published may be obtained from the Wagner Free Institute of Science, Philadelphia 21, Pennsylvania.

NOMINATIONS FOR MEMBERSHIP

In accordance with Article 3, Chapter 1 of the By-Laws of the Society the Secretary submits the following names of applicants for election to membership for consideration by the Members of the Paleontological Society.

BANDY, ORVILLE LEE. Dept. Geology, Univ. Southern California, Los Angeles 7, Calif. B.S., 1940; M.S., 1941, Oregon State College; Ph.D., 1948, Indiana University. Assistant Professor of Geology, Univ. Southern California. Interested in micropaleontology. Sponsored by W. H. Easton and Robert E. Stevenson.

BLUNDELL, CECIL ROBERT KNIGHT. Dept. Geology, The University, St. George's Square, Sheffield, England. B.Sc. 1946, Wales. Lecturer in geology, Sheffield University. Interested in invertebrate paleontology. Sponsored by P. C. Sylvester-Bradley and H. E. Vokes.

BURSCH, JACOBUS GEORGE. c/o Phillips Oil Co., Apartado 1031, Caracas, Venezuela. Ph.D., 1945, Univ. of Basle, Switzerland. Micropaleontologist, Phillips Oil Co. Interested in micropaleontology. Sponsored by Hans E. Thalmann and Ely Mencher.

COLEMAN, P. J. University of Western Australia, Nedlands, W. A., Australia. B.Sc., Univ. of Australia. Research Fellow in Paleontology, Univ. of Western Australia. Interested in invertebrate paleontology. Sponsored by Curt Teichert and Edmund D. Gill.

COLLINSON, CHARLES WILLIAM. Dept. Geology, State Univ. Iowa, Iowa City, Iowa. A.B., 1949, Augustana College. Research Assistant in Invertebrate Paleontology, State Univ. Iowa. Interested in invertebrate paleontology. Sponsored by A. K. Miller, Carlton Condit, and Bernhard Kummel.

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ADDITIONAL NOMINATIONS FOR MEMBERSHIP

BURNS, JAMES RICHARD, Box 1541, University Station, Charlottesville, Va. A. B., 1949, Univ. of Virginia. Graduate student in geology; interested in invertebrate paleontology. Sponsored by Joseph K. Roberts and H. E. Vokes.

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JAMES, ELLEN L., Dept. of Geology, Univ. of Oregon, Eugene, Ore. A.B., 1947, Oregon State Coll. Graduate student and departmental assistant, Univ. of Oregon; interested in invertebrate paleontology. Sponsored by H. E. Vokes and Donald A. Myers.

JELETZKY, JURIJ ALEXANDER, Geological Survey

of Canada, Ottawa, Canada. M.A., 1938; Ph. D. (approx. equivalent), 1941, Univ. of Kiev, Ukraine. Geologist, Geol. Survey Canada; interested in invertebrate paleontology, especially late Jurassic and Cretaceous Cephalopoda. Sponsored by A. Scott Warthin and R. T. D. Wickenden.

KEMPF, JAMES HENRY, Box 1733, University Station, Charlottesville, Va. A.B., 1949, Univ. of Virginia. Graduate student in geology; interested in invertebrate paleontology. Sponsored by Joseph K. Roberts and Thomas W. Amsden.

KOPF, MAX J., 750 Elmwood Ave., Buffalo 22, N. Y. Insurance salesman and amateur paleontologist; interested in Paleozoic Echinodermata and the Machaeridia. Sponsored by G. Arthur Cooper, R. S. Bassler and Alfred R. Loeblich, Jr.

LA ROCQUE, JOSEPH ALFRED AURÈLE, Dept. Geology, Ohio State Univ., Columbus 10, Ohio, B. A., 1945, Ottawa Univ.; M. Sc., 1947, Ph. D., 1948, Univ. Michigan. Assistant Prof. Geology, Ohio State Univ.; interested in invertebrate paleontology, especially Lower Paleozoic Pelecypoda. Sponsored by Grace A. Stewart and Edmund M. Spieker.

SCHNEIDER, ALLAN F., School Mineral Industries, Penna. State College, State College, Pa. B S., 1948, Beloit College. Graduate student, Penna. State College; interested in invertebrate paleontology. Sponsored by Frank M. Swartz and H. E. Vokes.

SCHREIBER, JOSEPH FREDERICK, JR., 5505 Lothian Rd., Baltimore 12, Md. A.B., 1948, The Johns Hopkins University. Graduate student and assistant in geology, The Johns Hopkins University; interested in invertebrate paleontology. Sponsored by Thomas W. Amsden and H. E. Vokes.

WEART, RICHARD CLAUDE, 307 West Elm St., Urbana, Ill. A.B., 1943, Cornell Coll., Ia.; M.S., 1948, Syracuse Univ. Graduate student (Fellow), Dept. Geology, Univ. Illinois; interested in micropaleontology. Sponsored by H. W. Scott, H. R. Wanless and Bernhard Kummel.

YEN, TENG-CHIEN, 5031, Copley Rd. Philadelphia 44, Pa. B.A., 1927, St. John's College; B. Sc., 1929, Univ. Nanking; D. Phil., 1937, Univ. Berlin; D. Sc., 1947, Univ. Glasgow. Research Geologist, Smithsonian Institution; interested in Mesozoic and Cenozoic non-marine invertebrate paleontology and paleoecology. Sponsored by C. Wythe Cooke, J. Brookes Knight and John B. Reeside, Jr.

NOMINATIONS FOR OFFICES IN THE PALEONTOLOGICAL SOCIETY FOR 1950

In accordance with the provisions of Chapter III, Section 2, of the By-Laws, the Council of the Paleontological Society announces the following nominations for offices in the Society for 1951:

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Chapter 3, Paragraph 2 of the By-Laws provides that "Any twenty members may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary at least sixty days before the Annual Meeting shall be printed, together with the names of the nominators, as special tickets."

ERRATUM

For: Pierre Parker, Fossil and Recent species of the pelecypod genera *Chione* and *Securella* from the Pacific Coast: Journal of Paleontology, vol. 23, no. 6, pp. 577–593, November, 1949. On p. 583, in explanation of figures *12*, *13*, *15*, *19*, *22:* after the words "Hypotype C. A. S. no. 5984b" insert the following: "*22*, (×1.3), hypotype C. A. S. no. 5984."

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